PAPERS AND PROCEEDINGS OF

THE ROYAL SOCIETY OF TASMANIA

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PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA

VOLUME 145

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PARROTS, PEOPLE AND PLANTS: URBAN TREE REMOVAL AND HABITAT LOSS FOR THE ENDANGERED SWIFT PARROT, *LATHAMUS DISCOLOR*

by Andrew B. Hingston and Marta Piech

(with one appendix)

Hingston, A.B. & Piech, M. 2011 (9:xii): Parrots, people and plants: urban tree removal and habitat loss for the endangered Swift Parrot, *Lathamus discolor. Papers and Proceedings of the Royal Society of Tasmania* 145: 1–4. ISSN 0080-4703. School of Geography and Environmental Studies, University of Tasmania, Private Bag 78, Hobart, Tasmania 7001, Australia (ABH*, MP). *Author for correspondence. Email: hingston@utas.edu.au

Swift Parrots, *Lathamus discolor,* breed predominantly in southeastern Tasmania, including around the city of Hobart. While breeding, they feed mostly on the nectar and pollen of Tasmanian Blue Gum, *Eucalyptus globulus,* and Black Gum, *E. ovata,* trees. Swift Parrots are regularly observed foraging on these floral products in the Hobart suburb of Mt Nelson, where the trees produce more flowers than those in adjacent bushland. To investigate trends in the availability of food for Swift Parrots breeding near Hobart, we surveyed people who live in Mt Nelson to ascertain the extent of removal of large eucalypt trees from their properties. The 294 respondents to our questionnaire reported the presence of 263 large *E. globulus* and 109 large *E. ovata* on their properties. However, respondents also stated that they had removed 88 large *E. globulus* and 25 large *E. ovata* trees in the past five to 10 years, and intended felling a further 13 large *E. globulus* and 15 large *E. ovata* trees in the near future. This represents the removal of almost 30% of large trees of both species within a decade, and suggests a decline in foraging habitat for Swift Parrots while breeding near Hobart.

Key Words: birds, threatened species management, urban ecology, wildlife, Swift Parrots, *Lathamus discolor,* Tasmanian Blue Gum, Black Gum, *Eucalyptus globulus, Eucalyptus ovata.*

INTRODUCTION

The Swift Parrot, *Lathamus discolor* (Shaw, 1790), is an endangered species of bird that breeds exclusively in Tasmania, mostly along the southeastern coast (Hindwood & Sharland 1963, Brown 1989, Brereton 1996). This area encompasses the Tasmanian capital city of Hobart, where nesting has been observed in surrounding bushland (Brown 1989, Brereton 1997).

During their breeding season, Swift Parrots rely predominantly on the nectar and pollen of Tasmanian Blue Gum, *Eucalyptus globulus* Labill., and Black Gum, *E. ovata* Labill., for food (Brown 1989, Brereton 1996, 1997, Gartrell *et al.* 2000, Gartrell & Jones 2001, Hingston *et al.* 2004). The reproductive success of Swift Parrots appears to be limited by food availability at this time, with fewer chicks fledged during seasons of poor flowering in *E. globulus* (Brereton 1996). During such seasons, the birds become more reliant on the smaller quantities of food produced by the flowers of *E. ovata* (Brown 1989).

Swift Parrots commonly forage from flowers of *E. globulus* and *E. ovata* in the outer Hobart suburb of Mt Nelson during their breeding season (Brereton 1996, 1997, Gartrell 2001, Hingston 2002, 2007). For example, 4–5% of the entire wild population of Swift Parrots was observed foraging in Mt Nelson throughout spring 2002 (Hingston 2007). Both *E. globulus* and *E. ovata* occur within the suburb, as well as in bushland around Mt Nelson (Hingston & Piech 2011). However, flower production on large trees of both species within suburban Mt Nelson is more prolific than on large trees in the surrounding bushland, apparently because suburban trees have denser canopies and less fire damage (Hingston & Piech 2011). Consistent with this, Swift Parrots appear to forage more often in these suburban trees than in nearby bushland trees (A. Hingston pers. obs.).

To better understand trends in the availability of eucalypt nectar and pollen for Swift Parrots breeding near Hobart, we investigated the extent of recent and projected removal of large *E. globulus* and *E. ovata* trees from suburban Mt Nelson.

METHODS

An anonymous survey was conducted among Mt Nelson residents in autumn 2008 to obtain information regarding large eucalypt trees on residential properties. All households of Mt Nelson, excluding flats, (n = 830) received a letter and questionnaire (appendix 1) with a return addressed envelope in their letterboxes.

The main purpose of the survey was to examine whether people have had, or intend to have, large *E. globulus* and *E. ovata* trees removed from their property. Large trees were defined as having a circumference greater than 2 m at 1.3 m above the ground. Questions in the survey were designed to elicit the following information: the ownership status of the property; the presence of large eucalypts on the property; any removal of large eucalypts in the past five to 10 years; and any intended eucalypt removal and reasons for that removal (appendix 1).

RESULTS

Two hundred and ninety-four completed responses were received. This represented a return of 35% of the 830 questionnaires originally dispatched. The majority of respondents (95%) were the owners of a Mt Nelson property, and only 5% were renting.

Presence of large eucalypts

The 294 respondents were divided almost equally between properties with large eucalypts (n = 144) and those without (n = 150). Of the 144 respondents with large eucalypts on their properties, 54.9% (n = 79) said *E. globulus* was present while 25.7% (n = 37) reported the absence of this species. Large trees of *E. ovata* were reported less often, with only 21.5% (n = 31) of the 144 respondents stating their presence and 43.7% (n = 63) their absence. The remaining respondents were unsure if the large eucalypts on their properties were of these species.

Most properties with large *E. globulus* or *E. ovata* had small numbers of these, and none had more than 20 of either species. Of the 79 respondents who reported large *E. globulus* on their property, 41.8% (n = 33) said they had only one of these, 22.8% (n = 18) had two and 11.4% (n = 9) had three. Only 24.1% (n = 19) of the properties with large *E. globulus* trees had more than three. Of the 31 respondents who reported large *E. ovata* on their property, 38.7% (n = 12) said they had only one and 32.3% (n = 10) had two. Properties with more than two large *E. ovata* trees were rather scarce (29.0%; n = 9).

The residents reported totals of 263 large *E. globulus* and 109 large *E. ovata* trees on the 294 properties. However, these are probably underestimates because, of the 144 respondents who stated that they had large eucalypts on their property, 19.4% (n = 28) were unsure if they had *E. globulus* and 34.7% (n = 50) were unsure if they had *E. ovata*.

Recent tree removal

A large proportion of respondents said that large trees had been removed from their properties in the past five to 10 years. While 56.8% of the 294 respondents (n = 167) reported that no large trees had been removed, 38.4% (n = 113) stated that some trees had been felled in this period. A small percentage of people (4.8%; n = 14) were not sure if large trees had been removed in the past five to 10 years.

More *E. globulus* than *E. ovata* have been cut down from the respondents' properties in the past five to 10 years. Among the 113 respondents who stated that large trees had been removed from their properties, 35.4% (n = 40) said this involved *E. globulus* while only 14.2% (n = 16) said *E. ovata* was removed. Most removals involved just one tree per property, with this being the case for 65.0% (n = 26) of properties from which *E. globulus* was removed and 56.2% (n = 9) of properties from which *E. ovata* was removed. However, this still represents the felling of 25.1% (n = 88) of the *E. globulus,* and 18.7% (n = 25) of the *E. ovata,* trees present five to 10 years ago. It is likely that greater numbers of trees of these species have been cut down because, of the 113 respondents who stated that they had removed large trees, 33.6% (n = 38) were unsure if this included *E. globulus* and 37.2% (n = 42) were unsure if this included *E. ovata*.

Rates of removal of the two species of eucalypt reflected their proportional abundances across the respondents' properties. There was no significant preference for removal of one species over another ($\chi^2 = 1.7$, $P > 0.1$).

Future tree removal

Most residents who responded to the questionnaire stated that they had no intention of removing any large trees in the future. This was the case for 73.8% (n = 217) of respondents. However, 15.6% (n = 46) said that they were planning on some tree felling, and 10.6% (n = 31) were not sure whether they would have trees cut down in the future.

Within the group of 46 residents who declared future tree removal, more than half said there would not be any *E. globulus* or *E. ovata* among the trees to be felled (n = 24 in both cases). However, 21.7% of these respondents (n = 10) intended cutting down *E. globulus* and 19.6% (n = 9) intended felling *E. ovata*. They intended removing up to three large trees of each species, equating to 4.9% (n = 13) of the *E. globulus* and 13.8% (n = 15) of the *E. ovata* currently present. These figures indicate no significant preference for future removal of one species over another ($\chi^2 = 0.038$, $P > 0.8$). However, it is likely that more trees of these species will be removed because, of the respondents who stated that they would have large eucalypts felled, 26.1% (n = 12) were unsure if this would include *E. globulus* and 28.3% (n = 13) were unsure if this would include *E. ovata*.

Reasons for eucalypt removal

When asked about the reasons for tree removal, some respondents did not answer the question and some gave more than one answer; hence the numbers below reflect the frequency at which a particular reason was given. The most common reason (n = 31) for future tree removal was the anticipated house damage caused by falling limbs, as well as fire. Another rationale was the inconvenience that trees may cause (n = 12); such as block the view, clog the gutters, make a mess, use too much water or spread roots. Tree sickness and its partial death or damage was also commonly given as a reason for removal (n = 10).

DISCUSSION

The responses of Mt Nelson residents to this survey indicate that there are hundreds of large *E. globulus* and *E. ovata* trees on residential properties within the suburb. Respondents reported the presence of 263 *E. globulus* and 109 *E. ovata* trees with circumferences of over 2 m at 1.3 m above the ground. However, these figures almost certainly underestimate the total numbers because they represent the numbers from only 35% of residential properties, and many of the respondents who stated that they had large eucalypts on their property were unsure if they had *E. globulus* or *E. ovata*. The abundance of these trees within the suburb, together with their propensity to flower profusely (Hingston & Piech 2011), results in the production of large quantities of nectar and pollen that provides potential food sources for Swift Parrots. Accordingly, Swift Parrots often use these resources in suburban Mt Nelson during their breeding season (Brereton 1996, 1997, Gartrell 2001, Hingston 2002, 2007).

The residents' responses indicate that these resources are likely to be declining. On the respondents' properties, at least 25.1% of the large *E. globulus* and 18.7% of the *E. ovata* trees have been removed in the past five to 10 years. This removal is likely to continue because respondents

indicated that a further 3.7% of the large *E. globulus,* and 11.2% of the large *E. ovata,* trees that were present five to 10 years ago will be felled soon. Hence, almost 30% of large trees of both species have either been removed in the past few years, or soon will be. This figure is likely to be an underestimate because many felled trees were not identified to species level, and therefore not included in these figures. The reasons given for tree removal were many and varied, but it is clear that people will continue to desire, and often need, to remove large trees from residential areas. This removal of large trees will, of course, be offset to some degree by continued growth in the sizes of remaining trees and the recruitment of new trees in the suburb. Rates of growth and recruitment will need to be quantified if we are to determine the maximum rate of tree removal that can occur without a net loss of foraging habitat for Swift Parrots in Mt Nelson.

It is unclear what effect any decline in food availability in Mt Nelson for Swift Parrots will have on their population. Because reproductive success of Swift Parrots appears to be limited by food availability during the breeding season (Brereton 1996), any decline in food availability across their breeding range is potentially detrimental. However, Swift Parrots attracted to urban areas can suffer high rates of mortality from collisions with human artefacts such as windows and fences (Brown 1989, Saunders *et al.* 2007), and this might become less frequent if food availability declines in urban areas such as Mt Nelson.

ACKNOWLEDGEMENTS

We thank Dr Emma Pharo for guidance on this project, and the many Mt Nelson residents who completed the questionnaire. This research was carried out under a University of Tasmania ethics clearance (Ethics Reference Number H10037).

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(accepted 4 July 2011)

APPENDIX 1

Note before you start: For the purpose of this particular study, a tree is considered to be large if its circumference (measured at 1.3 m above ground) is 2 m or more.

Q1. Please tick one:
❑ I am the owner-occupier of a Mt Nelson property
❑ I am renting a Mt Nelson property

Q2. Do you have any large eucalyptus trees on your property?
❑ Yes (Go to Question 3) ❑ No (Go to Question 7)

Q3. Do you have any large Blue Gums (*Eucalyptus globulus*) on your property?
❑ Yes (Go to Question 4)
❑ No (Go to Question 5)
❑ I'm not sure (Go to Question 5)

Q4. How many large Blue Gums (*Eucalyptus globulus*) do you have on your property (if the number is more than 10, can you estimate how many?) _____
_____

Q5. Do you have any large Black Gums (*Eucalyptus ovata*) on your property?
❑ Yes (Go to Question 6)
❑ No (Go to Question 7)
❑ I'm not sure (Go to Question 7)

Q6. How many large Black Gums (*Eucalyptus ovata*) do you have on your property (if the number is more than 10, can you estimate how many?) _____
_____

Q7. Have you had any large trees removed from your property in the past 5–10 years?
❑ Yes (Go to Question 8) ❑ No (Go to Question 9)

Q8. How many large trees have been removed from your property in the past 5–10 years and what species were they? (i.e. 1 x Blue Gum, approx. 4 x Black Gum, 1 x name unknown, etc.) _____
_____
_____
_____
_____
_____
(If you're not sure what the exact number was, please estimate how many. If you don't know the name of the species, write "name unknown")

Q9. Are you planning on having any large trees removed from your property in future?
❑ Yes (Go to Questions 10 & 11)
❑ No (Go to Question 12)
❑ Not sure (Go to Question 12)

Q10. Can you name the number and species of the large trees to be removed? (i.e. 1 x Blue Gum) _____
_____
_____
_____
_____
_____

Q11. Briefly state the reason(s) why you want to have the tree(s) removed. _____
_____
_____
_____
_____
_____

Q12. It would help to know your location. If you are not comfortable with providing your street number, then could you please provide your street name and tick one of the areas below.

Address _____
_____

Areas

❑ The Bends
❑ Mt Nelson Primary School area (between the Mt Nelson Water Reservoir at the top of Bend 7 and Mt Nelson Store)
❑ Signal Station area (between Mt Nelson Tavern and Signal Station)
❑ Mt Nelson Oval area (between Mt Nelson Tavern and Mt Nelson Store, including Rialannah Rd)
❑ Hobart College area (between Mt Neson Store and beginning of Proctors Rd)

Q13. Please tick the box below if you would like a summary of the results forwarded to you. Please note that if you tick the box, you need to provide your postal address (see Question 12)
❑ Yes, I would like to receive a summary of the results

Thank you for completing the questionnaire.

Please forward the questionnaire to the following address using the self-addressed envelope:

Attn: Marta Piech,
School of Geography and Environmental Studies,
University of Tasmania,
Private Bag 78, Hobart, Tasmania 7001.

MESSAGE IN A BOTTLE – A TALE OF TWO TRIASSIC TEMNOSPONDYL (LABYRINTHODONT) FEMORA FROM TASMANIA

by Kim Akerman and Andrew Rozefelds

(with one text-figure and two plates)

Akerman, K. & Rozefelds, A.C. 2011(9:xii): Message in a bottle – a tale of two Triassic temnospondyl (labyrinthodont) femora from Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 145: 5-8. ISSN 0080-4703. 4 Dorset Street, Moonah, Tasmania 7009, Australia (KA*); Queensland Museum, GPO Box 3300, South Brisbane, Queensland 4101, Australia (ACR*). *Authors for correspondence: Emails: kimakerman@tastel.net.au and andrew.rozefelds@qm.qld.gov.au

The history surrounding the discovery and study of some of the earliest Triassic temnospondyl bones found in Tasmania is unravelled and the significance of these bones is discussed. Both bones are likely to have been collected as a result of the quarrying of sandstone (between 1855 and 1857) for the building of the current Tasmanian Government House.

Key Words: temnospondyl, labyrinthodont, Triassic, early records, Tasmania, museology.

INTRODUCTION

In 1997 the senior author, while exploring the antique shops of Hobart, found in Suffolk Park Antiques an intriguing small, nineteenth-century, clear glass bottle. Labelled as "message in a bottle", it did indeed contain a note on a slip, cut from a visiting card, together with a wafer-thin, sub-triangular piece of dark, porous material (pl. 1). The handwritten note read "section shaft humerus labryinthodont, sandstone quarry, Hobart, 1856, Tas Museum". A further annotation, written at right angles to the preceding note, appears to read "Pro R.S.T 1898–9". Pro R.S.T. is an abbreviated reference to the *Papers and Proceedings of the Royal Society of Tasmania*, 1898–99. This issue of the journal included a short note by W.H. Twelvetrees and W.F. Petterd describing and illustrating two labyrinthodont bones from Tasmania lodged in the Tasmanian Museum and Art Gallery (TMAG) collection. Here we trace the history of the two temnospondyl (labyrinthodont) bones, review the significance of these specimens and propose an explanation as to how part of one specimen came to be in the Suffolk Park Antiques shop.

PLATE 1

Original bottle, showing the wedge of bone and handwritten label. The handwritten note reads "section shaft humerus labryinthodont, sandstone quarry, Hobart, 1856, Tas Museum". A further annotation, written at right angles to the preceding note, reads "Pro R.S.T 1898–9".

DISCOVERY AND STUDY

One of the temnospondyl bones was obtained from Dr Joseph Milligan (1807–1884), formerly of Hobart, Tasmania, and was collected, date unknown but prior to 1861, from a sandstone quarry near the current Government House (Clarke 1861) (fig. 1). The new Government House was constructed, from 1855 to 1857, using sandstone quarried on-site (Newman 2005), and the bones were probably found at this time. The original specimen was sent by Milligan to England, where it was examined by Richard Owen, the foremost anatomist of the nineteenth century, and plaster copies were made of the original which was returned to Milligan. In 1897, Twelvetrees and Petterd received a cast of this bone (previously referred to as TMAG Z163, but recently registered as TMAG Z3553) from Dr H. Woodward, Keeper of Collections at the British Museum.

Angela Milner, Natural History Museum, London (pers. comm. 2011), notes that a "coloured plaster cast, undoubtedly used to replicate the specimen [is] in our collections under register number NHMUK R 500". She also notes that the cast was presented by Richard Owen in 1884 to the Natural History Museum and there is a handwritten note with it that reads "Cast of humerus of Labyrinthodont Reptile from sandstone, probably Carboniferous, Tasmania. The original with Joseph Milligan, Esq". On the reverse side of the label one of the British Museum (Natural History) staff has written: "try *Eosaurus* of Marsh", referring to the great American palaeontologist Othniel Charles Marsh (1831–1899). *Eosaurus* literally means "dawn lizard", although it is now recognised as representative of an extinct group of Palaeozoic labyrinthodonts (pl. 2). Milner also pointed out that the cast was referred to by Lydekker (1890) as "genus non det." and correctly as the "cast of a femur; from strata of unknown age in Tasmania".

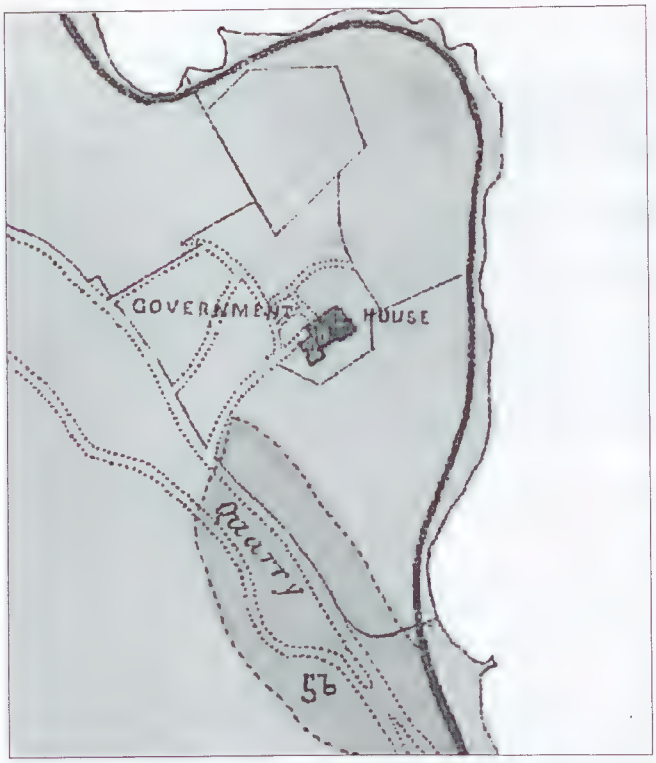

FIG. 1 — Extract of map (from Krause 1884) showing the position of a large quarry near Government House. A smaller quarry, which is not shown, is now a water feature in the grounds of Government House.

A second temnospondyl bone (TMAG Z163; in two pieces) was found in 1856 at the Government House Quarry. The temnospondyl bone passed into the hands of the Director of Public Works, Mr W. P. Kay, who in turn presented it to the museum (Anonymous 1857). Alexander Morton, Director of the Tasmanian Museum, brought this specimen to the attention of Twelvetrees and Petterd. Their findings were presented to The Royal Society of Tasmania in May 1899 and the paper was published the following year. The paper, which included a photomicrograph of a transverse section through this specimen (TMAG Z163), described both specimens (Z163 and Z1553) as two left humeri of labyrinthodont amphibians; to which they attributed a Late Permian or Early Triassic age.

Watson in David & Sussmilch (1931) reported the specimen as a reptile, and David (1950) regarded the specimen as a stegocephalian. Cosgriff (1974) identified "it" as a temnospondyl labyrinthodont and confirmed Lydekker's (1890) interpretation that they were femora, not humeri; he noted that the femora of Triassic temnospondyls are very uniform and therefore could not be assigned to a particular family. Possibly because both bones are left femora and are similar in size and appearance, various authors, including Camp & Banks (1978) and Cosgriff (1974) have erroneously assumed that Twelvetrees & Petterd (1900) had described a single bone. Previous curators at the Tasmanian Museum and Art Gallery had also incorrectly assumed that there was a single specimen and the old display label (pl. 2.) is therefore confusing as the reference to Owen pertains to Z3553 and on the reverse the text pertains to Z163.

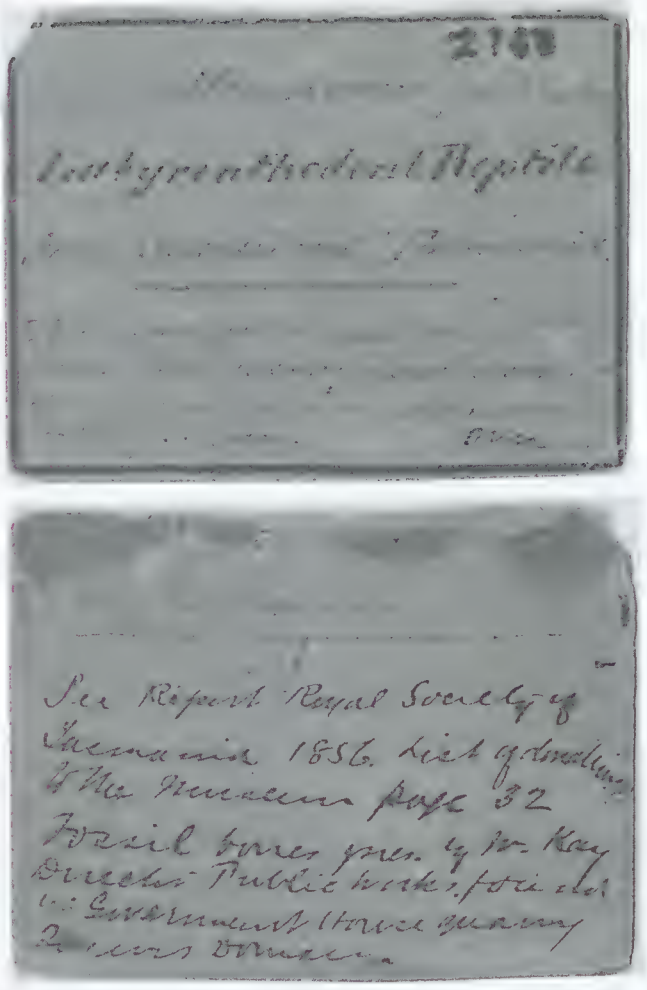

PLATE 2
Original display label which includes information pertinent to both TMAG Z3553 and TMAG Z163.

SIGNIFICANCE AND AGE OF THE TEMNOSPONDYL BONES

These specimens are some of the earliest temnospondyl bones found in Tasmania and Australia. While there is no reason necessarily to assume that they came from the same species of temnospondyl, the two bones were collected from the same area which makes this possibility more likely. This site is now mapped as the Early Triassic Knocklofty Sandstone, or its stratigraphic equivalents (Farmer 1979). Twelvetrees and Petterd's publication is significant because it was the first report of temnospondyls from Tasmania, a group of labyrinthodonts which are now recognised as common elements of the Triassic faunas of the State (Cosgriff 1974). The quarries near Government House were the first Triassic fossil vertebrate site to be found in Tasmania and have yielded the two femora and an undescribed fish spine (A. Milner pers. comm. 2011). Recently Warren *et al.* (2011) have proposed that the type specimen of the temnospondyl *Bothriceps australe* Huxley, 1859 that was described by Huxley (1859) from Australia, but of uncertain age and provenance, was also probably collected from Tasmania at about the same time.

THE BONE IN THE BOTTLE

The piece of bone in the bottle is a section of TMAG Z163 from the Government House Quarry which was cut to prepare the original section. So the question arises – how did it get into a Hobart antique shop? Suffolk Park Antiques had purchased the bottle at auction in 1977, when Sargisons, jewellers of Hobart, had shed most of its stock and fittings. It seems likely that Sargisons, which has a long and distinguished history reaching back into the late 1800s, may well have been given the task of making the original sections of the femur that were used in the photomicrographs made in 1897–1898. As jewellers, Sargisons would have been equipped with the fine saws and wheels capable of sectioning the precious fossil with the minimum of loss or destruction. The piece of bone in the bottle had possibly been retained as a souvenir of the unusual commission.

ACKNOWLEDGEMENTS

Angela Milner provided advice on Tasmanian collections held in the Natural History Museum. Stephen Forsyth provided help in accessing some of the early literature. Anthony Curtis kindly photographed the original bottle, wedge of bone and hand-written note. The authors thank Patrick Quilty and the editor, Margaret Davies, for their comments which have significantly improved this note.

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SIZE AND CHARACTERISTICS OF AGGREGATIONS OF MOON JELLYFISH (*AURELIA* SP.) IN TASMANIA, AUSTRALIA

by Christine M. Crawford, Natalie A. Moltschaniwskyj and Simon Willcox

(with four text-figures, one plate and one table)

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Dense aggregations of moon jellyfish, *Aurelia* sp., occurred in four of eight summers from 1978/79 to 2004/05 in the Huon Estuary, southern Tasmania, causing significant mortality of farmed Atlantic Salmon. This study investigated the biological characteristics of this jellyfish as part of a larger study examining factors influencing these aggregation events. Aggregations of medusae in the Huon Estuary were intensively sampled over 50 days in 2004/05. They typically had a strongly delineated structure throughout the water column, with a relatively high density of medusae at maturity, then the aggregations rapidly disappeared (size at maturity for 50% of the population was 101 mm bell diameter for females, 90 mm bell diameter for males). The discrete structure of the aggregations enabled relatively accurate estimates of the biomass of the *Aurelia* sp. population when growth rate was at its maximum. The number of aggregations in the estuary, their sizes and density of medusae were estimated from aerial photographs, by divers, and underwater video records. Mean density in the aggregations was 71 medusae m^{-3}. They contained approximate totals of 174 million *Aurelia* sp. medusae, wet weight of 28,600 t, and 39.2 t of carbon. Our observations suggest that the main advantage of forming these complex aggregations is to enhance fertilisation success.
Key Words: *Aurelia* sp., jellyfish blooms, aggregations, density, reproduction, Huon River, Tasmania.

INTRODUCTION

Moon jellyfish, *Aurelia* spp., are found in marine and estuarine environments worldwide and can concentrate into dense aggregations within enclosed or semi-enclosed water bodies (e.g., Lucas *et al.* 1997, Purcell *et al.* 2000). Aggregations are often promoted by physical properties of the water body in which they occur and are commonly believed to facilitate sexual reproduction, rather than act as a defence against predation or targeting food sources (Graham *et al.* 2001, Lucas 2001). The presence of large-scale aggregations of medusae, as a function of favourable conditions, has substantial ecological and economic consequences (Purcell *et al.* 2007).

The distribution, abundance and life history characteristics of the genus *Aurelia* are highly variable spatially and temporally (e.g., Schneider & Brehrends 1994, Lucas *et al.* 1997). The pelagic medusa stage generally occurs seasonally and lives for several months (Lucas & Williams 1994, Miyake *et al.* 1997), but in some populations, medusae will live for 12 months or more (Kinoshita *et al.* 2006).

Aurelia medusae are voracious feeders and are capable of modifying the seasonal composition and abundance of the planktonic community (Schneider & Brehrends 1994, Lucas *et al.* 1997). Secondary effects of high grazing pressure include increased phytoplankton biomass through reduced grazing pressure by copepods (Lindahl & Hernroth, 1983, Olsson *et al.* 1992, Møller & Riisgård 2007a) and decreased food availability for other zooplanktivores, which can have impacts through the food chain (Purcell & Arai 2001). Given their widespread distribution, occurrence in large aggregations and capacity to alter trophic dynamics, jellyfishes are potentially important consumers and transformers of energy and nutrients in the marine ecosystem (e.g., Watanabe & Ishii 2001, Pauly *et al.* 2009, Pitt *et al.* 2009).

Determining the abundances and sizes of jellyfish in the oceans has proved difficult because of their large sizes, fragility and patchy distributions, both horizontally and vertically, and because their gelatinous bodies are difficult to tag (Purcell 2009). Also, the high water content of their tissues makes acoustic sampling difficult, although combined acoustic soundings and video recordings can monitor relatively reliably some jellyfish species, provided the target species can be distinguished from other co-occurring species acoustically (Båmstedt *et al.* 2003, Alvarez Columbo *et al.* 2009). Consequently, estimates of the extents, causes and effects of jellyfish blooms have rarely been conducted on a large scale (Purcell 2009).

Aurelia sp. medusae periodically occur in dense monospecific aggregations in the sheltered waterways of southeast Tasmania, Australia (pl. 1). The medusae are morphologically similar to *Aurelia aurita*; however, they are genetically distinct from other species of *Aurelia* and have been designated as *Aurelia* sp. 7 (Dawson *et al.* 2005).

Growth, survival and reproduction of the sessile, asexual, colonial phase of this species has been found to be regulated by a combination of density-dependent factors and environmental conditions, which are consequently important to the formation of jellyfish aggregations (Willcox *et al.* 2008). These aggregations, however, were largely unnoticed until they caused the deaths of cultured Atlantic Salmon in Tasmania, valued at millions of dollars. The objective of this study was to describe the biological characteristics of this species, as part of a larger study investigating mechanisms driving the intermittent occurrence of *Aurelia* sp. aggregations in southeast Tasmania. This included growth and reproduction of individuals in the aggregations, and estimating aggregation size and total biomass of medusae in the system. To achieve this, we developed a method to assess

PLATE 1
Bloom of Aurelia *sp. in the Huon Estuary, Tasmania, as viewed from a light plane at 1000 ft.*

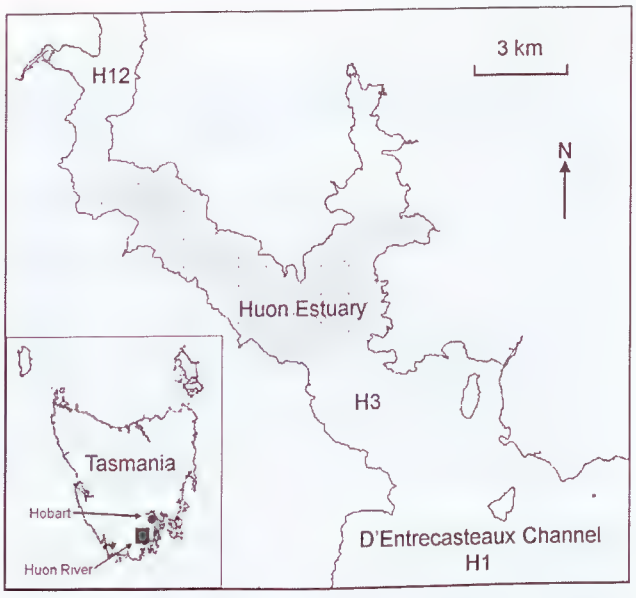

FIG. 1 — Location of the Huon Estuary in southeast Tasmania, Australia. The stippled area shows the section of the estuary where medusa aggregations were observed during the summer of 2002/03.

the abundance of jellyfish by combining aerial photography, underwater video photography and net sampling.

MATERIALS AND METHODS

The abundance of *Aurelia* sp. medusae and macrozooplankton in the Huon Estuary in southern Tasmania was estimated from plankton samples taken at three locations: H1, H3 and H12 (fig. 1) every 4–6 weeks from March 2001 to March 2003 and every 1–3 weeks when medusae were abundant. Samples were collected using a 65 cm diameter bongo net with 500 µm and 315 µm mesh fitted with General Oceanics flow meters. We used larger-than-standard mesh for zooplankton to sample large volumes of water for *Aurelia* sp. ephyrae and small medusae. Plankton tows were oblique from 10 m to the surface at a constant speed of 2–3 knots for 3 min at each location; abundances were standardised as numbers per litre.

Bloom population dynamics

Dense aggregations of *Aurelia* sp. medusae were found only over a 2-month period, from December 2002–January 2003 in a 10-km section of the Huon Estuary (fig. 1). Ten aggregations of moon jellyfish were randomly selected and observed on seven separate days in January 2003. A small boat equipped with a GPS mapping system, echo sounder and underwater camera were used to locate and determine the size, shape and depth distribution of the aggregations. Medusae were sampled from randomly selected aggregations during daylight hours using a 40 cm diameter 1 mm mesh plankton net fitted with a General Oceanics flow meter. Oblique tows from ~5 m depth at a constant speed of 0.5–1.5 knots were made within aggregations for 30–180 s, depending on density of medusae. A sub-sample of 20–30 medusae was examined alive and another 20–30 were preserved in buffered 4% formalin for assessment of maturity.

The bell diameter (BD in mm) of each medusa was measured as the distance between the tips of opposite rhopalia (marginal sense organs). The amount of shrinkage (reduction in BD) during preservation was estimated by measuring BD on 30 live medusae before they were stored in 4% formalin, and then again after 22 weeks in preservative, giving the relationship:

$$BD_{(live)} = 1.22 * BD_{(preserved)} \ (n=30, R^2=0.65).$$

All preserved BD measurements were adjusted by this relationship to give the live BD for data analysis. Wet weight (WW) was measured to the nearest gram after medusae were lightly shaken to remove excess water. The relationship between WW and BD was represented by the equation:

$$WW = 1.12x10^{-4}*BD^{2.81} \ (n = 305, R^2 = 0.97).$$

We measured dry weight (DW in g) after drying medusae to a constant weight at 50°C (Larson 1986); DW was 3.7% of WW. Accurate measurement of medusa DW is difficult because bound water is retained after drying (Larson 1986, Doyle *et al.* 2007); our measure is similar to that recorded by Uye & Shimauchi (2005) for *Aurelia aurita* in the Inland Sea of Japan. We converted DW to carbon content (C) with the relationship C = 3.6% DW in Uye & Shimauchi (2005), which was determined at salinities >30, as found in the Huon Estuary. Conversions involving DW and C differ depending on ambient salinity and this conversion may provide a conservative estimate of carbon content because the ratio of C:DW is lower than values tabulated for *Aurelia* spp. in lower salinities (Purcell 2009).

Growth rate of medusae was calculated by fitting an exponential relationship to BD data, with strobilation predicted to have occurred on 1 October 2002, based on strobilation occurring in late August to early October in 2003 and 2004 (Willcox *et al.* 2008). Mean ephyra BD was assumed to be 2 mm on strobilation (Båmstedt 1990). Using this initial size at strobilation and the size data for medusae collected from 5 December 2002–31 January 2003, the average BD was used to estimate a rate of growth over the spring and summer. However, measurements of BD from the last two days of sampling showed a changed growth pattern and were not included in the growth equation. Those animals were drifting down the estuary near the surface and were the only remaining medusae found. Mean daily

growth rate was calculated for each period on the basis of increments in BD:

$$Growth = \frac{BD_2 - BD_1}{\Delta t}$$

where BD_1 and BD_2 are the mean bell diameters for each period, and Δt is the number of days between the two collection times. Estimates of growth of individuals in the population using a modal size progression analysis (Palomares & Pauly 2009) was not possible because the data were collected intensively over several weeks and not over months or years; size also increased very rapidly and did not attain an asymptote.

Sex and maturity stage were defined as:
Juvenile (j): gonad thin, clear, indistinguishable as male or female;
Immature male (im): gonad clear/opaque, spermatogenic follicles beginning to form in the epithelium;
Mature male (mm): gonad dark pink/purple, follicles well developed;
Immature female (if): gonad clear/opaque, developing oocytes visible, large late-stage oocytes few or absent;
Mature female (mf): gonad opaque pink/purple, many large late-stage oocytes;
Brooding female (bf): gonad as for MF, with fertilised eggs and planula larvae in brood pouches on oral arms.

Gonads from a total of 39 mature and brooding females over five sampling days (January 19, 20, 22, 24 and 30) were examined. The diameters of an arbitrary selection of approximately 100 oocytes from each female were measured with an ocular micrometer on a microscope at 50 x power. Differences in oocyte size frequency distributions among the five days were compared using a χ^2 test of independence. A logistic model of proportional maturity at length using maximum likelihood estimation assuming a binomial error distribution (Quinn & Deriso 1999) was fitted to the data to determine the BD at which 50% (s50) and 95% (s95) of male and female medusae were mature.

Aggregation numbers and sizes

The total population of *Aurelia* sp. in the Huon Estuary and adjacent waters was estimated from an aerial survey of aggregations on the afternoon of 23 January 2003 at altitudes of 300–1500 m (method modified from Purcell *et al.* 2000; Graham *et al.* 2003). Low oblique photographs were taken of each aggregation and geographical features were included (e.g., points, bays, boat ramps, fish farms, roads, houses) for size calibration. Cameras were fitted with filters to remove the effect of glare (Houghton *et al.* 2006). Images were geo-rectified (Wolf & Dewitt 2000) to fit a scale map of the Huon Estuary and aggregation outlines were digitised and the surface area calculated. We confirmed that aggregations observed from the air were *Aurelia* sp. medusae on the day of the aerial survey with a small boat equipped with an underwater camera. A random search of the estuary using the echo sounder and underwater camera did not find any aggregations that were not visible from the air.

The vertical distribution of aggregations observed in the aerial survey on 23 January 2003 was assumed to be similar to the observations and measurements of aggregations in the Huon Estuary made by divers, underwater cameras and echo-sounders on each sampling day in January 2003. Water depth at the location of each aggregation was determined from bathymetric charts and the number of medusae in each aggregation was estimated from the mean density of medusae in aggregations (n = 4 over 3 days) measured with a 40 cm diameter 1 mm mesh plankton net as above on three consecutive days, i.e., the days before, on and after the aerial photographs were taken.

RESULTS

Bloom population dynamics

Aurelia sp. medusae were found in large dense aggregations in the Huon Estuary in southeast Tasmania only during the summer of 2002/03 in water temperatures ranging from 16.1–17.5°C and salinities of 32.8–34.0 at 1 m depth in the middle estuary. Medusae were first collected on 5 December 2002 when mean bell diameter (BD) was 24.6 mm ± 5.88 (standard error). BD of medusae sampled from the aggregations increased exponentially from 1 October 2002–24 January 2003 according to the equation BD (mm) = $e^{0.042*days}$, equivalent to an increase of 4.2 % BD d^{-1} (fig. 2). Maximum mean size (171.8 ± 17.6 mm) was reached on 24 January and the largest medusa sampled was 246 mm. This peak was followed by a seven-day period when the mean BD of individuals in the population decreased and all medusae observed showed disintegration of the marginal region.

Fifty percent of female *Aurelia* sp. medusae reached maturity at 101 mm BD and 95% at 125.6 mm. Fifty percent of males reached maturity at 90 mm BD and 95% at 131 mm. Maturity was not as tightly constrained by size in males as it was in females, which had a larger difference in BD between 50% maturity and 95% maturity. The maturity stage distribution of females in the aggregations differed significantly over January (χ^2 = 28.03, degrees of freedom (df) = 5, P <0.001), with the proportion of mature females in the population increasing through time (fig. 3). The first mature medusae were seen on 19 January when 78% of males and 65% of females were mature. By 30 January (day 56) 100% of males and 89% of females were mature. The proportion of females carrying planula larvae (bf) increased in during January (fig. 3). The sex ratio over

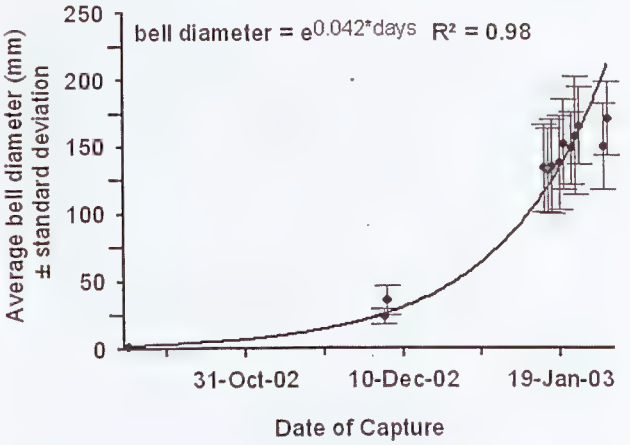

FIG. 2 — Changes in average bell diameter (BD) (with standard deviation) of Aurelia *sp. medusae in the Huon Estuary from 1 October 2002–31 January 2003, n=645 individuals. The size of the ephyra on 1 October 2002 (the first data point) was estimated from the literature (Båmstedt 1990). The fitted line describes an exponential increase in average bell diameters.*

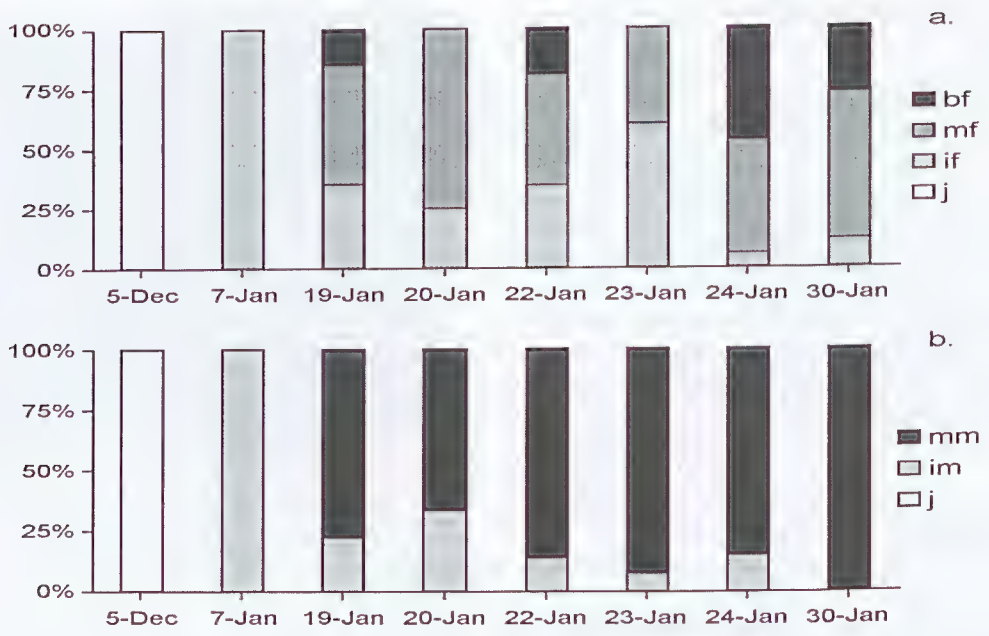

FIG. 3 — Percent frequency of the maturity stages for the Aurelia *sp. population on each sampling day for a) female medusae (j=juvenile, if=immature, mf=mature, bf=brooding), and b) male medusae (j=juvenile, im=immature, mm=mature) in the Huon Estuary in the summer of 2002/03.*

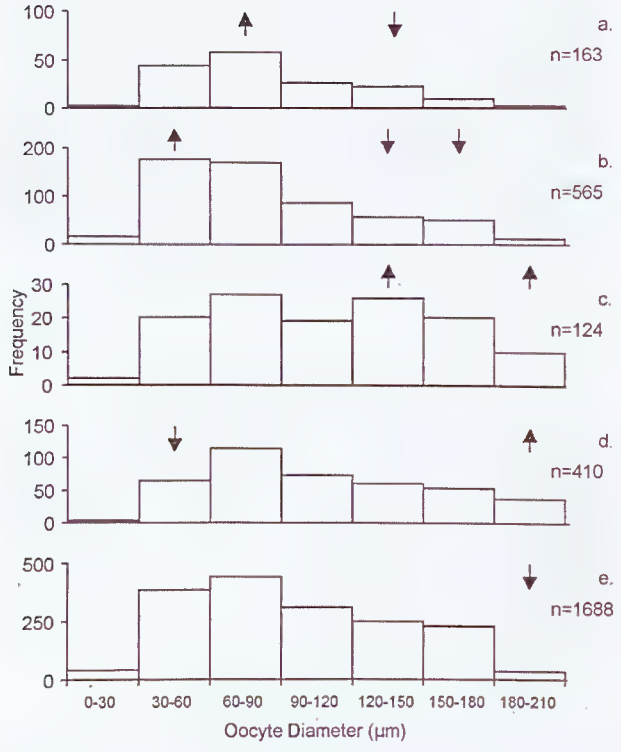

FIG. 4 — Aurelia *sp. oocyte size frequency distributions for mature medusae from the Huon Estuary. (a) 19 January (4 medusae), (b) 20 January (7 medusae), (c) 22 January (4 medusae), (d) 24 January (6 medusae), (e) 30 January (18 medusae). Arrows indicate the size class that had more (↑) or fewer (↓) oocytes than expected if the size distributions were the same on each sampling occasion. n=number of oocytes measured.*

the summer was approximately 1:1, although there was some fluctuation among days during the season. The proportion of males was only 25% on day 56, the last day of sampling.

There was a significant difference in the size frequency distribution of oocytes through time ($\chi^2 = 140.8$, df = 24, P <0.001), with mature female gonads containing more small oocytes than expected on 19 January and more large mature oocytes than expected one week later when the jellyfish were at maximum size (fig. 4). On the last sampling day (56) of the season, the oocytes in the gonads predominately were immature and those medusae were beginning to disintegrate; the large, discrete aggregations previously sampled could not be located.

Aggregation number and size

Aggregations generally had very sharp, planar boundaries (±12 m) on all sides including the top and bottom. The tops of aggregations were readily visible from the surface and were 1–3 m below the surface during relatively stable sea state conditions. Observations by both underwater camera and divers suggested that the aggregations were of uniform density throughout the water column; however, density was not measured at discrete locations within aggregations to confirm this impression. The bottom boundaries of aggregations paralleled the sea floor 1–3 m above the bottom. Densities of medusae in the aggregations over the sampling period ranged from 18–270 m^{-3} with an average of 133 ± 37.2 medusae m^{-3}.

A total of 22 aggregations were observed and photographed in the lower Huon Estuary during an aerial photography flight on day 49. These aggregations were clearly visible from the air, appeared pale green in colour (pl. 1) and ranged from circular to elliptical in shape. We assumed that all aggregations in the estuary were visible at the surface at the time of the flight because all aggregations of *Aurelia* sp. detected over the summer by visual and acoustic methods

and plankton nets extended from about 1.5 m above the bottom to within about 1.5 m of the surface and were clearly visible from the boat during daylight and stable sea state conditions.

The mean density of medusae in four aggregations was estimated to be 71 ± 32.7 m^{-3} based on plankton tows in the aggregations on three days. The largest aggregation observed during the summer had a volume >600 000 m^3 and contained an estimated 100 million individuals. The largest aggregation on the day of the aerial survey was estimated to be 233 000 m^3 with an estimated 23 million medusae. The smallest aggregation measured was 5200 m^3 and contained approximately 370 000 individuals.

On 23 January, the total estimated volume of aggregations in the Huon Estuary was 2.46 million m^3. The total number of medusae in the aggregations was estimated to be 174.4 million with a WW of 28 600 metric tons (t) incorporating 39.2 t of carbon (table 1). By use of the Uye & Shimauchi (2005) estimate of 9.2% as a likely mean daily specific carbon ration, determined from field studies of gut content for *A. aurita* of comparable size range and at similar salinities to *Aurelia* sp. in the Huon Estuary, it was estimated that the whole population would have consumed about 3.6 t C d^{-1} (table 1). Alternatively, by use of the respiration equation for *Aurelia* spp. medusae in Purcell (2009), the minimum daily specific ration would be ~6.4%, or about 2.4 t C d^{-1}.

DISCUSSION

Bloom population dynamics

The occurrence of *Aurelia* sp. medusae in southeast Tasmania followed an annual cycle with recruitment of medusae in early spring followed by exponential growth over summer. Assuming ephyrae were produced at a similar time of year in 2002 to when they were observed being released from a polyp colony in the D'Entrecasteaux Channel (fig. 1) in 2003 and 2004 (Willcox *et al.* 2008), growth was slow initially before the observed exponential growth in warmer summer waters. This growth pattern is typical of many *Aurelia* species populations (e.g., Schneider & Behrends 1994, Lucas 2001, Uye & Shimauchi 2005). Towards the end of the 2002/03 summer the positive growth of medusae ceased and the condition of medusae deteriorated. Within 10 days of maximum medusae size, the large aggregations were absent and no medusae were observed. This rapid growth pattern followed by sudden disappearance of medusa is not suited to length-frequency analysis of growth, although this method of assessment of growth has been recommended for longer lived *Aurelia* sp. populations (Palomares & Pauly 2009).

TABLE 1
***Aurelia* sp. estimates of bloom size and food requirements of medusa in the Huon Estuary on 23 January 2003**

Parameter	Estimated values
Total volume of aggregations	2 456 696 m^3
Mean density	71 + 32.7 medusae.m^{-3}
Total number of medusae	174.4 million
Wet weight biomass	28 600 tons
Dry weight biomass	1 058 tons
Total carbon	39.2 tons
Estimated daily carbon ration	2.4–3.6 metric tons day^{-1}

The availability of sufficient food is critical to sustaining the growth and condition of other species of *Aurelia* (Olesen *et al.*, 1994, Lucas *et al.* 1997, Ishii & Tanaka 2001). The biomass of mesozooplankton sampled in the 315 µm mesh net peaked in abundance at the same time as the medusae in January 2003 in the Huon Estuary (Willcox 2006). *Aurelia* sp. medusae size, growth rate, deterioration and disappearance tracked the zooplankton biomass with a lag of 5–10 days, which suggests a strong link between food supply and *Aurelia* sp. growth and maturation; however, *Aurelia* spp. medusae also consume small prey, including microzooplankton (Uye & Shimauchi 2005, Malej *et al.* 2007, Purcell 2009), which were not sampled in our study. Nevertheless, the growth of medusae may have been affected by a reduction in food availability in the Huon Estuary. It was not possible to determine whether the decline in large zooplankton biomass in the Huon Estuary was due to predation by medusae. Dense populations of scyphozoans can reduce zooplankton biomass (e.g., Schneider & Behrends 1994, Lucas *et al.* 1997), and decreases in growth rate after a fast initial rate often result from changes in the environment induced by the organisms themselves (Coyne 1973).

The reduction in size of individuals in the aggregation is indicative of negative growth of the medusae and is characteristic of *A. aurita*; they survive through periods of low food availability by using resources held in body tissues (Hamner & Jenssen 1974, Lucas 2001). Negative growth of up to 70% reduction in size after 100 days of starvation can occur (Hamner & Jenssen 1974). Slowed growth of *A. aurita* in summer may not be due to food limitation, but to energy re-allocation from somatic to reproductive growth (Lucas 2001); however, in our study, large proportions of males and females were fully mature before growth rates slowed. Negative growth following gamete release was observed by Ishii & Tanaka (2001), who concluded that the reduction in medusa size was independent of food availability. The apparent reduction in growth of *Aurelia* sp. may have been due to the disappearance or death of large individuals after gamete release.

An abrupt decline in numbers is relatively common in jellyfish populations (e.g., Uye & Shimauchi 2005, Titelman *et al.* 2006) and may occur due to senescence following spawning (Mills 1993, Lucas 2001), whole-animal predation, grazing by predators and parasites/symbionts, such as hyperiid amphipods (Gröndahl 1988, Mills 1993), sudden unusual hydrographic events and hydraulic processes (Møller & Riisgård 2007b), or lack of food. Although "spent" female gonads were not observed at the end of the season, the highest percentage of females with planula larvae in the gonads was captured on day 49 when medusa size peaked. After that time, few medusae were caught and their condition had deteriorated, suggesting that spent animals rapidly disappeared and the last jellyfish sampled were among the few remaining to spawn. The death of animals with remaining reproductive potential is common among short-lived species with indeterminate life spans (Stearns 1992). There was no evidence of an influx of parasites towards the end of the season.

Aggregation number and size

The aggregations formed by *Aurelia* sp. in the Huon Estuary were mostly very distinct with sharp vertical boundaries extending from the surface to the bottom; they each formed a "wall" of jellyfish that moved within the estuary. Aggregations maintained their discrete structure with high and relatively uniform jellyfish density over many hours despite the upper and lower layers of the water column moving in different directions. This was achieved by a highly complex pattern of active, coordinated movement of medusae throughout the aggregations (Willcox 2006). Evolutionary advantages to aggregation were suggested by Hamner *et al.* (1994), Purcell *et al.* (2000) and Rakow & Graham (2006) as increased fertilisation success or retention in convergences where zooplankton prey are concentrated. Other suggestions include retention in inshore waters near suitable sites for settlement of planktonic larvae and reduction in predation (Purcell *et al.* 2000), or that groups of medusae orient to currents to avoid damaging levels of sheer and turbulence (Rakow & Graham 2006). Our observations of aggregations in the Huon Estuary suggest that they would enhance reproductive success, as evidenced by the high levels of brooding females and the rapid disappearance of the aggregations after most jellyfish reached maturity. These aggregations also would maintain spawning jellyfish within the estuary, which has strong tidal currents, surface freshwater flows and short flushing time, near substrates suitable for settlement of planula larvae. Avoidance of predation appears to be of low importance in this area because no predators of jellyfish are known to occur in sufficient quantities in the region to warrant the maintenance of aggregations. There was no evidence of directional movement of aggregations (Willcox 2006), suggesting that the synchronised activity of individuals may be more important to maintain the aggregation structure than to facilitate their location in areas of higher prey abundance.

Aurelia spp. are tolerant to a wide range of environmental conditions and display great plasticity in their population structure. Populations of *Aurelia* sp. in southeastern Tasmania also are characterised by interannual variability in the occurrence of aggregations, by having a strongly delineated aggregation structure throughout the water column, relatively high density of large medusae at maturity and rapid disappearance with no records of strandings. The discrete structure of the aggregations with vertical walls of jellyfish to within 1–3 m of both the surface and the bottom provided the rare opportunity to estimate the biomass of the moon jellyfish population in the Huon Estuary when growth rate was at its maximum, with a relatively high level of accuracy. The estimated WW biomass of 28 600 tons and daily C ration of 2.4–3.6 t d^{-1} provides an approximation of medusa grazing pressure in the estuary. The effects of this large *Aurelia* sp. biomass on the Huon Estuary ecosystem are unknown; however, it is likely that they modify the flow of energy and nutrients through the local ecosystem (e.g., Ishii & Tanaka 2001, Uye & Shimauchi 2005). Further studies on the compounding effects of *Aurelia* sp. blooms at different trophic levels are required; however, these aggregation events occur sporadically.

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A REVISED KEY AND NOTES ON THE TASMANIAN GENERA OF CHRYSOMELINAE (COLEOPTERA: CHRYSOMELIDAE)

by David W. de Little

(with four text-figures, three plates and one table)

de Little, D.W. 2011 (9:xii): A revised key and notes on the Tasmanian genera of Chrysomelinae (Coleoptera: Chrysomelidae). *Papers and Proceedings of the Royal Society of Tasmania* 145: 17–26. ISSN 0080-4703. Tasmanian Museum and Art Gallery, GPO Box 1164, Hobart, Tasmania 7001, Australia. Email: dcdelittle@bigpond.com

Fifteen genera of Chrysomelinae (Coleoptera: Chrysomelidae) are recognised from Tasmania, Australia. An illustrated key to the adults of genera in Tasmania is provided, together with notes on Tasmanian representative species and their host plants where known. Several species are regarded as pests of Tasmanian forest and plantation trees.

Key Words: Chrysomelinae, Chrysomelidae, leaf beetle, Tasmania, host, pest, forest, tree plantation, *Calomela, Chalcolampra, Chalcomela, Dicranosterna, Ethomela, Eugastromela, Ewanius, Faex, Geomela, Palaeomela, Paropsides, Paropsis, Paropsisterna, Peltoschema, Trachymela.*

INTRODUCTION

The leaf beetle sub-family Chrysomelinae contains a number of species that are prominent defoliators of *Eucalyptus* (*sensu lato*) spp. and *Acacia* spp. in Tasmania, especially the Tasmanian Eucalyptus Leaf Beetle, *Paropsisterna bimaculata* (Olivier, 1807), the Southern Eucalyptus Leaf Beetle, *P. agricola* (Chapuis, 1877) and the Fireblight Beetle, *Peltoschema orphana* (Erichson, 1842). Daccordi & de Little (2003) provided a key to adults of the Tasmanian genera of Chrysomelinae, based on the key of Matthews & Reid (2002) for South Australian genera, but overlooked the genera *Eugastromela* Lea, 1929 and *Chalcomela* Baly, 1856.

Reid (2006) revised the Australian genera of Chrysomelinae, providing detailed generic descriptions and including genera with species successfully introduced into Australia as biological control agents. The most significant impact of this work in relation to the Chrysomelinae of Tasmania is the synonymy of the economically important genus *Chrysophtharta* Weise, 1901 with *Paropsisterna* Motschulsky, 1860 (senior synonym).

The current paper revises the generic key in Daccordi & de Little (2003) in line with Reid's (2006) revision and includes the two overlooked genera. Notes are provided on the currently recognised Tasmanian genera of Chrysomelinae, and, where known, their host-plants. *Chrysolina* spp. introduced into Tasmania as biological control agents against Boneseed, *Chrysanthemoides monilifera* (L.) T. Norl., are not considered at the current time to have successfully established (Ireson 2002), and this genus is therefore not included in the key.

MATERIAL EXAMINED

Specimens from the following collections were examined: Tasmanian Museum and Art Gallery (Rosny, Tasmania) (TMAG); and Tasmanian Department of Primary Industry, Parks, Water and Environment (New Town, Tasmania) (TASAG).

THE TASMANIAN CHRYSOMELINAE

The Chrysomelinae fauna of Tasmania resembles a subset of the continental Australian fauna, but lacks the genera from the tropical/subtropical rainforest. The two landmasses were connected in the late Pleistocene, and there is similarity between island and continental floras. Tasmanian floristic endemism is greatest in the climatically aseasonal-wet western region of the island and shows a strong archaic Gondwanan influence (Rozefelds 2008).

Of the 43 native genera of Chrysomelinae that occur in mainland Australia (Reid 2006, Reid *et al.* 2009), 14 also occur in Tasmania, together with the one endemic monotypic genus, *Ewanius* Reid, 2002, which occurs on the archaic Gondwanan element, *Nothofagus* Blume. The genera occurring on plant genera *Eucalyptus* L'Hér. and *Acacia* Mill., also widely spread throughout Australia, are relatively well known and collected due to the prominence and economic importance of their hosts. Genera occurring on other hosts in Tasmania are relatively poorly known and infrequently collected, e.g., *Ewanius*, and it is quite possible that new species and even new genera await discovery.

Paropsides is the most widely distributed of the genera occurring in Tasmania. It occurs from eastern Siberia through eastern Asia, Indonesia, New Guinea and Eastern Australia (Daccordi 1994). Reid (2006), however, considers this genus is probably polyphyletic. The endemic monotypic *Ewanius* has interesting possible archaic Gondwanan links with the monotypic *Novacastria* Selman & Lowman, 1983 in eastern mainland Australia, and the monotypic *Araucanomela* Bechyné & Bechyné, 1973 in southern Chile, both also on *Nothofagus* (Reid 2002, Daccordi & de Little 2003).

KEY TO GENERA OF CHRYSOMELINAE IN TASMANIA

1. Procoxal cavities closed, or slightly open (fig. 3A) (2)
- Procoxal cavities widely open (fig. 3F) ..... (4)

2. Third tarsal segment not bilobed (fig. 4G) .....
..... *Chalcolampra* (fig. 1, pl. 1A)
- Third tarsal segment deeply bilobed (fig. 4M) ... (3)

3. Prosternum with two symmetrical carinae; metasternum with plicae (fig. 3A) ..... *Ethomela* (pl. 1C)
- Prosternum without carinae; metasternum without plicae .....*Palaeomela* (pl. 1D)

4. Claws simple (fig. 4H); coxal lines on ventrite 1 deviating from hind coxal cavities (fig. 4K); last article of palpi pointed (fig. 4I); pygidium with deep longitudinal median groove (fig. 4J) ..... (5)
- Claws dentate or appendiculate (figs 4A,E,F); coxal lines following cavity margins (fig. 4C); last article of palpi securiform (figs 4B,N); quadrate or elongate-cylindrical; pygidium without deep median groove ..... (6)

5. Elytra tuberculate and at least partly non-striate; prosternal process broad and flat with sides more-or-less parallel and ridged (fig. 2) ..... *Eugastromela* (pl. 1B)
- Elytra non-tuberculate and striate; prosternal process not as above ..... *Geomela* (pl. 1F)

6. Prosternal process with angled lobe on either side of basal plate (fig. 3F), or with lobe reduced to small round swelling (*Paropsis rubidipes* Blackburn, 1901)..... ..... *Paropsis* (pl. 1E)
- Prosternal process not as above ..... (7)

7. Prothoracic hypomera with deep, curved groove (fig. 3G) ..... *Calomela* (pl. 2A)
- Prothorax hypomera without groove ..... (8)

8. Trichobothrial setae absent from pronotum ..... (9)
- Pronoum with trichobothrial setae at anterior and posterior angles, or only at posterior angles (figs 3B,C) ..... (12)

9. First article of maxillary palpi ventrally flat, with anterior edge straight and sharply keeled (fig. 4N) .... *Dicranosterna* (pl. 2B)
- First article of maxillary palpi not as above ... (10)

10. Apices of mid and hind tibiae expanded with row of short spines on distal face of usually triangular expansion (fig. 4L) ..... *Faex* (pl. 2C)
- Tibiae not expanded externally at the distal apex ... . (11)

11. Elytra with irregular puncturation, acervate or verrucose ..... *Trachymela* (pl. 2D)
- Elytra with regular rows of punctures, or if irregular, then non-verrucose ... *Paropsisterna* (pls 2E, 2F, 3A)

12. All corners of pronotum with trichobothrial setae (Fig. 3B) ..... (13)
- Trichobothrial setae present on posterior angles of pronotum only (fig. 3C) ..... *Peltoschema* (pl. 3B)

13. Claws dentate or appendiculate (figs 4E,F) 14
- Claws simple, without basal tooth (fig. 4D) .... *Chalcomela* (pl. 3C)

14. Claws dentate (fig. 4E), epipleura extended vertically (fig. 3E)..... *Paropsides* (pl. 3D)
- Claws appendiculate (fig. 4F), epipleura visible from sides (fig. 3D) ..... *Ewanius* (pl. 3E)

NOTES ON GENERA

In his revision of the Australian Chrysomelinae, Reid (2006) gives diagnostic descriptions of adults of genera occurring in Tasmania which are not repeated here.

Chalcolampra

Blanchard, C. E. 1853: *Voyage au Pôle Sud et dans l'Océanie sur les corvettes l'Astrolabe et la Zélée; exécuté par ordre du Roi pendant les Années 1837–1840 sous le commandement de M. J. Dumont d'Urville - Zoologie*, 4, p. 328. (figs 1, 4G, pl. 1A)

Material examined: *C. thoracica* Baly, 1855; Hobart, Tasmania; Col.: A.M. Lea (no date); ♀ and ♂; TASAG.

This is a widely distributed possibly polyphyletic genus occurring in southeast Asia and New Zealand as well as Australia where there are approximately 25 species (Daccordi 1994, Reid 2006). Six species are recorded from Tasmania (table 1). Specimens of *C. rufinoda* Lea, 1904 (fig. 1) were not examined by the author.

A wide range of host families is listed for the genus in Australia, including Asteraceae, Lamiaceae, Scrophulariaceae and Pittosporaceae (Reid 2006, Jurado-Rivera *et al.* 2009). Hosts of the species in Tasmania are unknown.

Ethomela

Lea, A. M. 1916: *Transactions of the Royal Society of South Australia* 40: p. 425. (fig. 3A, pl. 1C)

Material examined: *E. hursti* (Blackburn, 1889); Tasmania; Col.: anon.; no date; TASAG; (labelled *Chalcolampra hursti* Blackburn).

This genus is endemic to Australia with 18 described and at least seven undescribed species (Reid 2006). Two species are recorded from Tasmania (table 1). Reported host families are Goodeniaceae (Reid 2006) and Asteraceae (Jurado-Rivera *et al.* 2009) but hosts of the Tasmanian species are unknown.

Palaeomela

Daccordi, M. 1996: *In* P.H.A. Jolivet & M.L. Cox (Eds): *Chrysomelidae Biology*, vol. 1: the Classification, Phylogeny and Genetics. SPB Academic Publishing, Amsterdam: p. 403. (pl. 1D)

No specimens are held in TASAG or TMAG or were examined by the author.

According to Reid (2006) the genus is endemic to southeastern Australia with two described and three undescribed species. Jurado-Rivera *et al.* (2009) give Proteaceae and Rubiaceae as host families. One species is recorded from Tasmania (table 1) and its host is unknown.

Eugastromela

Lea, A. M. 1929: *Transactions of the Royal Society of South Australia* 53: p. 64. (fig. 2, pl. 1B)

No specimens are held in TASAG or TMAG and none were examined by the author.

Reid (2006) considers the genus endemic to southeastern Australia and to contain three species. One species is known in Tasmania (table 1), and its presence there was overlooked by Daccordi & de Little (2003). Host plants are unknown (Reid 2006).

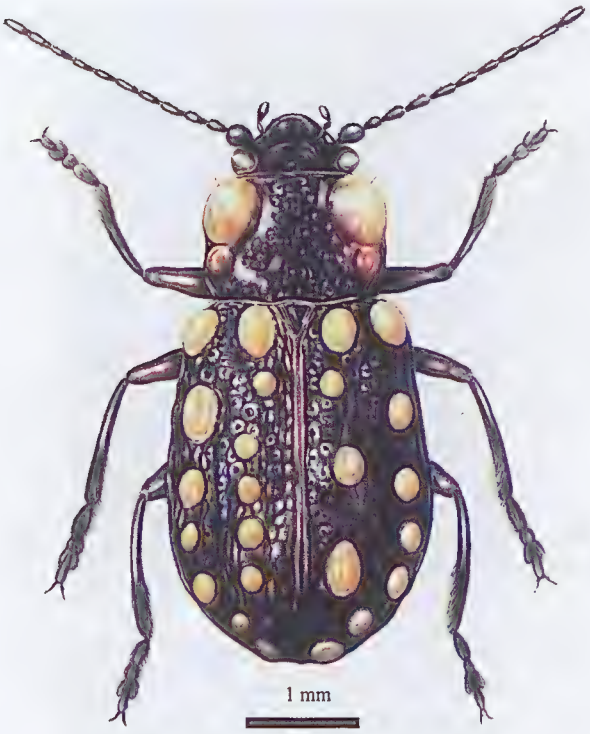

FIG. 1 — Chalcolampra rufinoda *Lea, 1904*

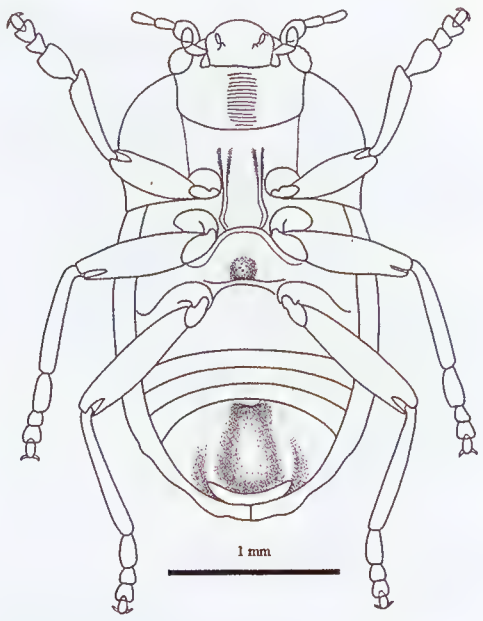

FIG. 2 — Eugastromela spiniventer *Lea, 1929, ventral view.*

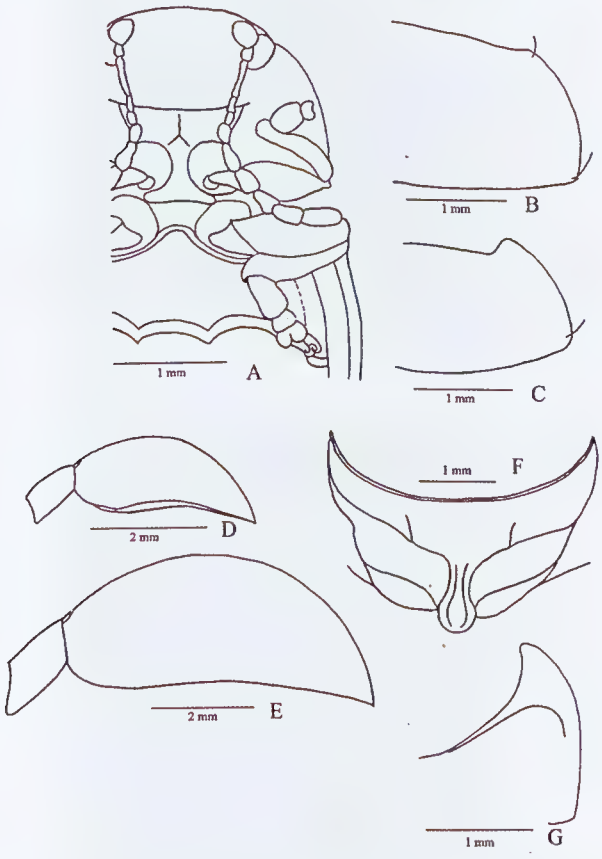

FIG. 3 — *A.* Ethomela hursti *(Blackburn, 1889), ventral view showing head and thoracic sternites. B.* Paropsides catherinae *Daccordi & de Little, 2003, pronotum with trichobothrial setae. C.* Peltoschema orphana *(Erichson, 1842), pronotum with trichobothrial setae. D.* Ewanius nothofagi *Reid, 2002, lateral view. E.* Paropsides catherinae, *lateral view. F.* Paropsis charybdis *Stål, 1860, prosternum. G.* Calomela maculicollis *(Boisduval, 1835), hypomeral groove.*

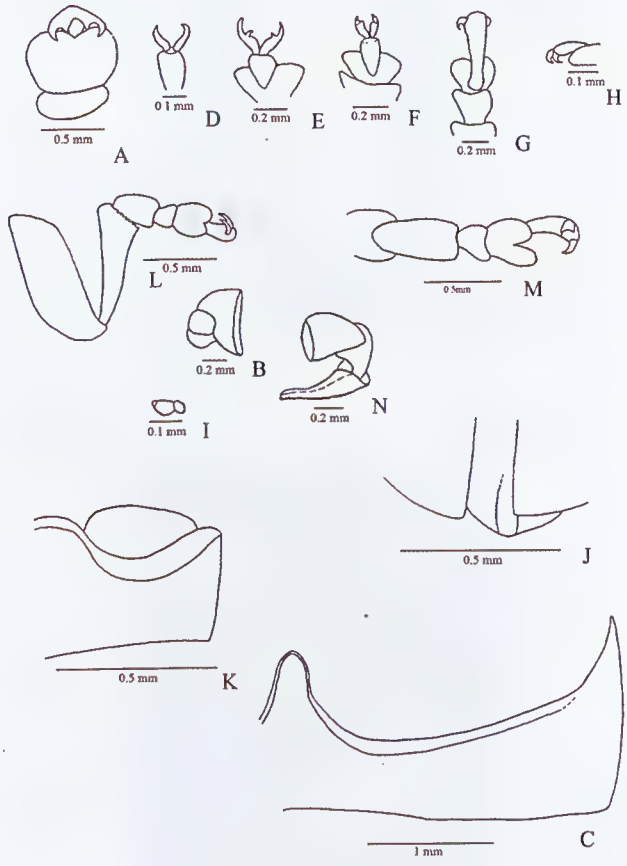

FIG. 4 — *A.* Paropsis charybdis *Stål, 1860, claw. B.* P. charybdis, *maxillary palp. C.* P. charybdis, *coxal line on ventrite 1. D.* Chalcomela cupripennis *(Baly, 1856), claw. E.* Paropsides catherinae *Daccordi & de Little, 2003, claw. F.* Ewanius nothofagi *Reid, 2002, claw.* G. Chalcolampra thoracica *Baly 1855, tarsal segments. H.* Geomela *sp., claw. I.* Geomela *sp., maxillary palp. J.* Geomela *sp., pygidial groove. K.* Geomela *sp. coxal line on ventrite 1. L.* Faex subfasciata planior *(Blackburn, 1898), leg showing expanded hind tibia. M.* Ethomela hursti *(Blackburn, 1889), tarsal segments. N.* Dicranosterna immaculata *(Marsham, 1808), maxillary palp.*

TABLE 1
Described Tasmanian Chrysomelinae genera and species

Taxon	References
Calomela Hope, 1840	Daccordi & de Little 2003
C. curtisi (Kirby, 1818)	
C. maculicollis (Boisduval, 1835)	
Chalcolampra Blanchard, 1853	Lea 1902, 1904, 1916, Reid 1993
C. aenea (Boisduval, 1835)	
C. constricta (Erichson, 1842)	
C. multinoda Reid, 1993	
C. pacifica (Erichson, 1842)	
C. rufinoda Lea, 1904	
C. thoracica Baly, 1855	
Chalcomela Baly, 1856	This paper
C. cupripennis (Baly, 1856)	
Dicranosterna Motschulsky, 1860	Daccordi & de Little 2003, this paper
D. immaculata (Marsham, 1808)	
Ethomela Lea, 1916	Lea 1902, 1929; Reid 2006
E. hursti (Blackburn, 1889)	
E. luteicornis (Erichson, 1842)	
Eugastromela Lea, 1929	Lea 1929
E. spiniventer Lea, 1929	
Ewanius Reid, 2002	Reid 2002
E. nothofagi Reid, 2002	
Faex Weise, 1901	Blackburn 1898
F. subfasciata planior (Blackburn, 1898)	
Geomela Lea, 1916	Lea 1916, 1917, Daccordi & de Little 2003
G. beatricis Daccordi & de Little, 2003	
G. bifoveata Lea, 1916	
G. bryophaga Lea, 1916	
G. chiarae Daccordi & de Little, 2003	
G. tasmaniensis Lea, 1917	
Palaeomela Daccordi, 1996	Daccordi & de Little 2003
P. cribricollis (Lea, 1929)	
Paropsides Motschulsky, 1860	Daccordi & de Little 2003
P. calliope (Blackburn, 1898)	
P. catherinae Daccordi & de Little, 2003	
P. nigrolineata (Lea, 1924)	
P. umbrosa (Chapuis, 1877)	
Paropsis Olivier, 1807	Selman 1983
P. aegrota elliotti Selman, 1983	
P. charybdis Stål, 1860	
P. deboeri Selman, 1983	
P. delittlei Selman, 1983	
P. dilatata Erichson, 1842	
P. porosa Erichson, 1842	
P. rubidipes Blackburn, 1901	
P. tasmanica Baly, 1866	
Paropsisterna Motschulsky, 1860	Lea 1902, Weise 1916, Blackburn 1899, Selman 1983; Reid 2006; this paper
P. agricola (Chapuis, 1877)	
P. aurea (Blackburn, 1899)	
P. bimaculata (Olivier, 1807)	
P. crocata (Boisduval, 1835)	
P. decolorata (Chapuis, 1877)	
P. laesa (Germar, 1848)	
P. lignea (Erichson, 1842)	
P. lineata (Marsham, 1808)	
P. morio (Fabricius, 1787)	
P. nobilitata (Erichson, 1842)	
P. nucea (Erichson, 1842)	
P. obliterata (Erichson, 1842)	
P. philomela (Blackburn, 1901)	
P. rufipes (Fabricius, 1801)	
P. subcostata (Chapuis, 1877)	
P. trimaculata (Chapuis, 1877)	
P. variicollis (Chapuis, 1877)	
Peltoschema Reitter, 1880	Lea 1902, Weise 1916, Daccordi & de Little 2003
P. delicatula (Chapuis, 1877)	
P. hamadryas (Stål, 1860)	
P. lepida (Erichson, 1842)	
P. oceanica (Boisduval, 1835)	
P. orphana (Erichson, 1842)	
P. tetraspilota diemensis (Blackburn, 1897)	
P. venusta (Erichson, 1842)	
P. vestalis Daccordi & de Little, 2003	
Trachymela Weise, 1908	Lea 1902, Weise 1916
T. acclivis (Blackburn, 1907)	
T. comma (Blackburn, 1896)	
T. ferrugata (Chapuis, 1877)	
T. papulosa (Erichson, 1842)	
T. rugosa (Chapuis, 1877)	
T. serpiginosa (Erichson, 1842)	

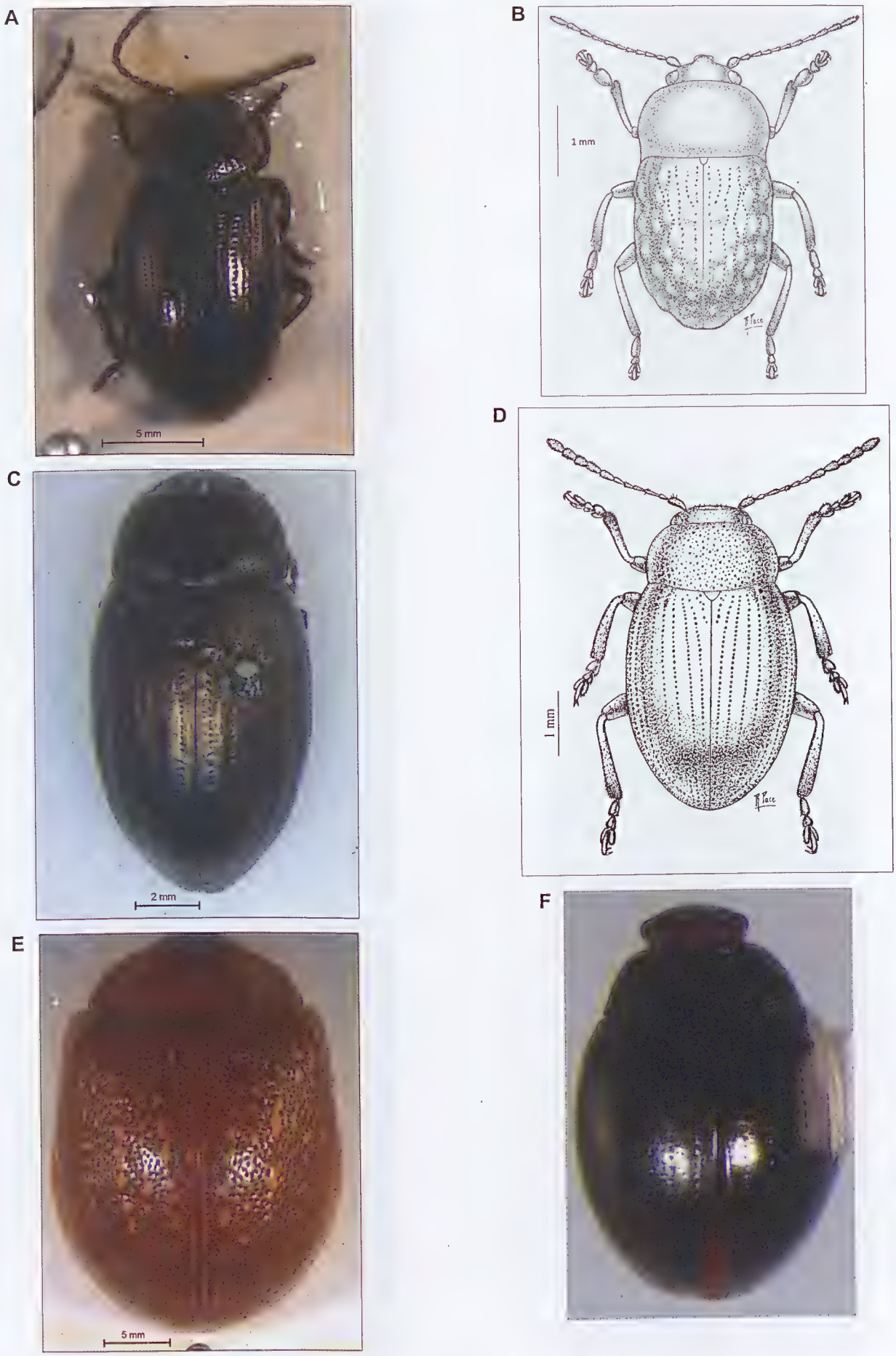

PLATE 1

Habitus images of Tasmanian Chrysomelinae, dorsal view. A. Chalcolampra thoracica *Baly, 1855.* B. Eugastromela spiniventer *Lea, 1904. C.* Ethomela hursti *(Blackburn,1889). D.* Palaeomela cribricollis *(Lea, 1929) (from Daccordi & de Little (2003)). E.* Paropsis tasmanica *Baly, 1866. F.* Geomela *sp.*

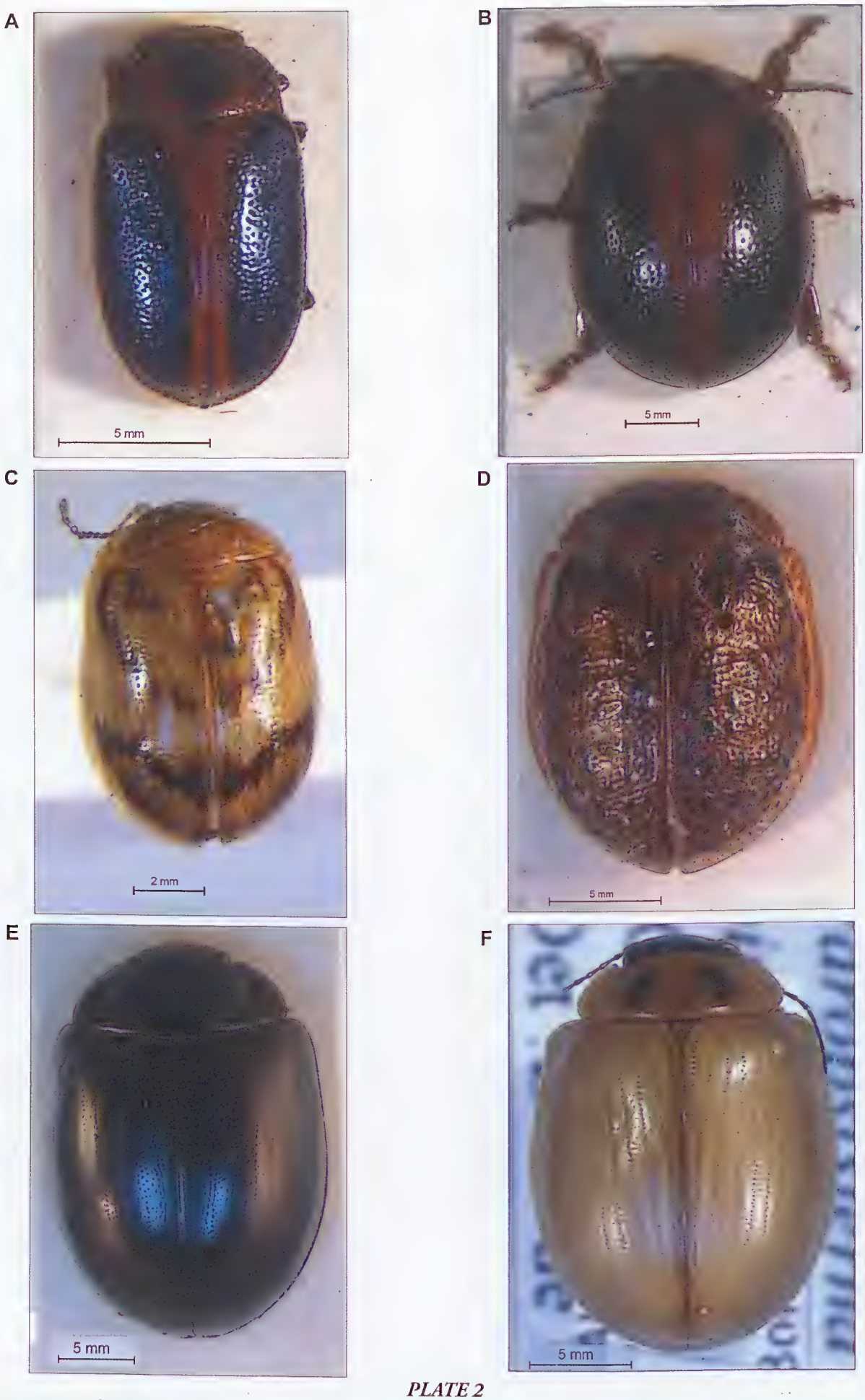

PLATE 2

Habitus images of Tasmanian Chrysomelinae, dorsal view. A. Calomela curtisi *(Kirby, 1818).* B. Dicranosterna immaculata *(Marsham, 1808). C.* Faex subfasciata planior *(Chapuis, 1877). D.* Trachymela comma *(Blackburn, 1896). E.* Paropsisterna morio *(Fabricius, 1787). F.* P. bimaculata *(Olivier, 1807).*

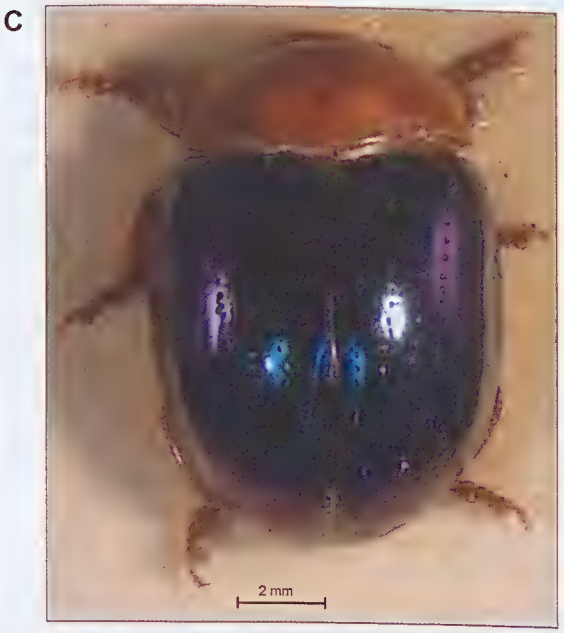

PLATE 3

Habitus images of Tasmanian Chrysomelinae, dorsal view. A. Paropsisterna philomela *(Blackburn, 1901) (from de Little (1979a) as* Paropsis *sp. 9). B.* Peltoschema orphana *(Erichson, 1842). C.* Chalcomela cupripennis *(Baly, 1856). D.* Paropsides catherinae *Daccordi & de Little, 2003. E.* Ewanius nothofagi *Reid, 2002.*

Geomela

Lea, A. M. 1916: *Transactions of the Royal Society of South Australia* 40: p. 397. (fig. 4H,I,J,K, pl. 1F)

Material examined: *Geomela* "sp.2"; Col.: anon; southwest Tasmania, 42°56'S, 145°50'E; litter; 18.ii.1977; Det.: JF Lawrence 1979; TMAG.

This genus is endemic to Australia with 13 described and several undescribed species (Reid 2006). Five species are recorded from Tasmania (table 1). Host plant families are Plantaginaceae (Jurado-Rivera *et al.* 2009), possibly Scrophulariaceae (Reid 2006). Host plants of Tasmanian species are unknown.

Paropsis

Olivier, A. G. 1807: *Entomologie, ou histoire naturelle des insectes, avec leur caractères géneriques et spécifiques, leur description, leur synonymie, et leur figure énluminée. Coléoptères.* Desray, Paris. Vol. 5. p. 596. (figs 3F, 4A,B,C, pl. 1E)

Material examined: *P. tasmanica* Baly, 1866; Col.: GH Hardy; Hobart; 8.xi.1913; TMAG. *P. charybdis* Stål, 1860; Col.: DW de Little; Tiger Creek, Tasmania; 25.viii.1973; TMAG.

This genus is native to Australia (70 species) and New Guinea (two species) (Reid 2006) occurring on the family Myrtaceae (Reid 2006, Jurado-Rivera *et al.* 2009).

Eight species and subspecies are recorded from Tasmania (table 1). Adults, larvae and eggs of all these species were described by de Little (1979a). *Paropsis rubidipes* Blackburn, 1901, a Tasmanian endemic species, is unique in having the right-angled flanges at the base of the prosternal process, a diagnostic character for almost all *Paropsis* species, reduced to rounded tubercles (Reid 2006). The host genus for all Tasmanian species is *Eucalyptus* (de Little 1979a).

Occasional defoliation damage to Tasmanian commercial forests is caused by three species. *Paropsis porosa* (Erichson, 1842) defoliates young seedlings of *Eucalyptus nitens* Maiden and *E. globulus* Labill. in plantations; *P. delittlei* Selman, 1983 defoliates *E. obliqua* L'Hér. regrowth forests and *E. nitens* plantations; and *P. charybdis* Stål, 1860 defoliates *E. nitens* plantations (de Little 1989). *Paropsis charybdis* is also introduced in New Zealand where it is a pest of cultivated eucalypts (Selman 1963).

Calomela

Hope, F. W. 1840: *The coleopterist's manual, part the third, containing various families, genera, and species of beetles, recorded by Linnaeus and Fabricius. Also, descriptions of newly discovered and unpublished insects.* Bridgewater, Bowdery & Kerby, London: p. 166. (fig. 3G, pl. 2A)

Material examined: *C. curtisi* (Kirby, 1818); Col.: GH Hardy; Hobart; 10.xi.1913; TMAG. *C. macullicollis* (Boisduval, 1835); Col.: GH Hardy; Hobart; 29.xi.1913; TMAG.

Calomela is restricted to Australia and New Guinea where there are approximately 45 species (Reid 2006). The host genus is *Acacia* (Fabaceae) (Reid 2006, Jurado-Rivera *et al.* 2009). Two species are recorded from Tasmania (table 1) where they are collected on *Acacia* spp.

Dicranosterna

Motschulsky, V. 1860: *In*: Schrenk (Ed.), *Reisen und Forschungen im Amurlande.* Vol. 2. St. Petersburg: p. 193. (fig. 4N, pl. 2B)

Material examined: *D. immaculata* (Marsham, 1808); Col.: JR Cunningham; Kingston, Tasmania; 25.v.1951; (labelled *Paropsis biplagiata* Boheman); TMAG.

This genus is endemic to Australia where there are 34 species described (Reid 2006) The host genus is *Acacia* (Fabaceae) (Reid 2006, Jurado-Rivera *et al.* 2009). One species is recorded from Tasmania (table 1) where it feeds on foliage of *A. dealbata* Link.

Faex

Weise, J. 1901: *Archiv für Naturgeschichte* 67: p. 165. (fig. 4L, pl. 2C)

Material examined: *F. subfasciata planior* (Blackburn, 1898); Col.: DW de Little; Woolnorth, Tasmania; 6.ii.1980; on *Melaleuca ericifolia*; Sm. TMAG.

Reid (2006) states *Faex* is endemic to Australia and has approximately 10 species. The host family is Myrtaceae (Reid 2006, Jurado-Rivera 2009).

The single Tasmanian subspecies (table 1) was collected from species of *Leptospermum* J. R. Forst. & G. Forst. and *Melaleuca ericifolia* (Myrtaceae) (D. de Little unpubl. data).

Trachymela

Weise, J. 1908: *Die Fauna Südwest-Australiens,* 2(1): p. 7. (pl. 2D)

Material examined: *T. comma* (Blackburn, 1896); Col.: JW Evans; Lake St Clair, Tasmania; x.1939; TMAG.

This genus of approximately 120 species is native to Australia and New Guinea (Reid 2006). The host family is Myrtaceae (Reid 2006, Jurado-Rivera *et al.* 2009).

Six species are recorded from Tasmania (table 1). A further three species have been observed (D. de Little unpubl. data) making a total of nine *Trachymela* spp. occurring in Tasmania. Eggs of most species are deposited under loose bark. Larvae are crepuscular in their feeding habits, and rest under loose bark during daylight hours (de Little 1979b). *Trachymela rugosa* (Chapuis, 1877) is the exception, ovipositing on foliage and larvae remaining on foliage during daylight. Eight of the Tasmanian *Trachymela* spp. are collected from *Eucalyptus* (de Little 1979b) and one species occurs on *Callistemon pallidus* (Bonpl.)DC., both family Myrtaceae.

Paropsisterna

Motschulsky, V. 1860: *In*: Schrenk (Ed.), *Reisen und Forschungen im Amurlande.* Vol. 2. St. Petersburg: p. 192. (pls 2E, F, 3A)

Material examined: *P. morio* (Fabricius, 1787); Col.: GH Hardy; Hobart; 2.ix.1916; (labelled *Paropsis nigerrima* Germar); TMAG. *P. bimaculata* Col.: GF Bornemissza; Weldborough, Tasmania; 20.i.1983; TMAG; *P. philomela* (Blackburn, 1901); Col.: AP Andrews; Lake Pedder, Tasmania; no date; TMAG.

Paropsisterna (*sensu lato)* was recently redefined by Reid (2006) to include *Chrysophtharta* Weise, 1901 (including *Niliosoma* Motschulsky, 1860, and *Sterromela* Weise, 1915). The redefined genus includes approximately 110 species and

is native to Australia and New Guinea (Reid 2006). The host family is Myrtaceae (Reid 2006, Jurado-Rivera *et al.* 2009).

In Tasmania the redefined genus includes 17 described species (table 1). A further four species as yet unidentified or undescribed are known to occur in Tasmania (D. de Little unpubl. data). All Tasmanian species feed on *Eucalyptus* hosts (de Little 1979b, Selman 1983) with the exception of *P. obliterata* (Erichson, 1842) which has been observed feeding on *Melaleuca ericifolia* and *Leptospermum scoparium* J.R. Forst. & G. Forst. (both Myrtaceae) (D. de Little unpubl. data).

Adults of many species formerly classified in *Chrysophtharta* have bright, iridescent colours in life that fade after death, e.g., *P. aurea* (Blackburn, 1899), *P. nobilitata* (Erichson, 1842). These species oviposit on foliage and larvae spend their entire developmental period on foliage, sometimes in gregarious feeding groups (e.g. *P. bimaculata P. agricola*). Species formerly classified in *Sterromela* oviposit under loose bark and have crepuscular feeding larvae like most *Trachymela* species. *Paropsisterna lignea* (Erichson, 1842) is ovoviviparous (de Little 1979b). *Paropsisterna philomela* (Blackburn, 1901) and *P. crocata* (Boisduval, 1835) are two relatively large and rare species where the normal ten rows of elytral punctures are indistinguishable.

The genus contains some notable pests of Tasmanian commercial forestry, especially *P. bimaculata* which defoliates regrowth forests of *E. obliqua*, *E. regnans*, F. Muell. and *E. delegatensis* R. T. Baker (Greaves 1966). *Eucalyptus nitens* plantations can be severely defoliated by both *P. bimaculata* and *P. agricola* (de Little 1989). Another species erroneously identified as *P. gloriosa* (Blackburn, 1899) (C. Reid pers. comm.) occasionally defoliates *E. nitens* plantations in Tasmania and has recently been discovered in Ireland defoliating cultivated glaucous foliage eucalypts (F. Horgan pers. comm.)

Peltoschema

Reitter, E. 1880: *Verhandlungen des naturforschenden Vereines in Brünn,* 18(1879): p. 4. (fig. 3C, pl. 3B)

Material examined: *P. orphana* (Erichson, 1842); Col.: DW de Little; Florentine Valley, Tasmania; 29.v.1973; (labelled *Pyrgo orphana* (Erichson)); TMAG.

This genus comprising approximately 100 species is endemic to Australia (Reid 2006). Host plant families are Fabaceae (Reid 2006, Jurado-Rivera *et al.* 2009) and Apocynaceae, Asteraceae and Myrtaceae (Jurado-Rivera *et al.* 2009). Species in this genus have also been referred to under the names *Pyrgo* Weise, 1901, *Pyrgoides* Aslam, 1968, and *Acacicola* Lea, 1903 (Reid 2006).

Eight species are recorded from Tasmania (table 1). The best known species is *P. orphana* (commonly known as Fireblight Beetle, which can cause extensive defoliation and death of Silver Wattle, *Acacia dealbata* Link (Elliott 1978, Simmul & Clarke 1999). Tasmanian *Peltoschema* species are collected from *Acacia* (Fabaceae) (Elliott 1978, Daccordi & de Little 2003, de Little unpubl. data).

Reid (2006) synonymised *P. vestalis* Daccordi & de Little, 2003 with *P. delicatula* (Chapuis, 1877) (senior synonym); however, M. Daccordi (pers. comm.) who studied the Chapuis types considers *P. vestalis* to be a valid species.

Chalcomela

Baly, J. S. 1856: *Transactions of the Entomological Society, London,* 3(7): p. 256. (fig. 4D, pl. 3C)

Material examined: *C. cupripennis* (Baly, 1856); Col.: JR Cunningham; Kingston, Tasmania; 11.ix.1951; (labelled *Stethomela purpureipennis* Lea); TMAG.

Chalcomela comprising 17 known species is native to Australia and New Guinea and its host plant families are Celastraceae, Elaeocarpaceae and Rubiaceae (Reid 2006).

Reid (2006) synonymised *Stethomela purpureipennis* Lea, 1916 with *C. cupripennis* and noted that the type locality for *C. cupripennis*, Melbourne, seemed unlikely to be correct as no other species of *Chalcomela* was recorded from south of Sydney. The occurrence of this species in Tasmania (table 1) supports the southern Australian distribution of *C. cupripennis* providing it is not an accidental introduction. The host plant is unknown.

Paropsides

Motschulsky, V. 1860: *In*: Schrenk (Ed.), *Reisen und Forschungen im Amurlande.* Vol. 2. St. Petersburg: p. 192. (figs 3B,E,4E, pl. 3D)

Material examined: *P. catherinae* Daccordi & de Little, 2003; Col.: DW de Little; Surrey Hills, Tasmania; on *Leptospermum* sp.; 14.xii.1977; TMAG.

Paropsides, with 25 Australian species, is the most widely distributed of the genera that occur in Tasmania, having a global distribution from eastern Asia to eastern Australia (Reid 2006). Australian host families are Myrtaceae and Fabaceae (Reid 2006), and Sapindaceae (Jurado-Rivera *et al.* 2009). The east Asian type species, *P. duodecimpustulata* (von Gebler, 1825) feeds on Rosaceae (Reid 2006).

Four species are known from Tasmania (table 1). Known hosts are *Oxylobium ellipticum* (Vent.) R. Br., *Pultenea juniperina* Labill. (Fabaceae), and *Leptospermum* spp. (Myrtaceae) (Daccordi & de Little 2003, de Little unpubl. data).

Ewanius

Reid, C.A.M. 2002: *Coleopterist's Bulletin,* 56(4): p. 589. (figs 3D,4F, pl. 3E)

Material examined: *E. nothofagi* Col.: M Daccordi; Lake Fenton, Mt Field NP, Tasmania; 6.xii.1998; TMAG.

This monotypic genus containing *E. nothofagi* (table 1) is endemic to Tasmania where it feeds on *Nothofagus cunninghamii* (Hook.f.) Oerst. and possibly on *N. gunnii* (Hook.) Oerst. (Nothofagaceae) (Reid 2002, Daccordi & de Little 2003, Reid 2006).

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CONTRIBUTIONS TO A CATALOGUE OF ALIEN PLANTS IN TASMANIA III

by Matthew L. Baker

(with four text-figures and three plates)

Baker, M. L. 2011(9:xii): Contributions to a catalogue of alien plants in Tasmania III. *Papers and Proceedings of the Royal Society of Tasmania* 145: 27–34. ISSN 0080-4703. Tasmanian Herbarium, Tasmanian Museum and Art Gallery, Private Bag 4, Hobart, Tasmania 7001, Australia. Email: Matthew.Baker@tmag.tas.gov.au

The status of six alien plant taxa recorded in Tasmania is discussed. *Cordyline australis* (G.Forst.) Endl., *Lupinus* x *regalis* Bergmans, *Pittosporum crassifolium* Banks & Sol. ex A.Cunn., *Pittosporum eugenioides* A.Cunn., *Pittosporum tenuifolium* Gaertn. and *Pittosporum undulatum* Vent. are ornamental taxa that are now recognised as naturalised in Tasmania. A description for each taxon is provided and distribution and habitat details are discussed. Keys to the Tasmanian species of *Lupinus* L. and *Pittosporum* Banks ex Gaertn. are included.
Key Words: naturalised, exotic, weeds, introduced, flora, *Pittosporum, Cordyline, Lupinus.*

INTRODUCTION

Management of Tasmania's alien flora requires an accurate and up-to-date account of taxa present. This paper is the third of a series (Baker 2005, 2007) which aims to ensure that taxa that become naturalised in Tasmania are formally recorded; that taxa that are present in Tasmania, but have not become fully naturalised ["sparingly naturalized" in the sense of Buchanan (2005) and Baker (2005)] are likewise recorded; that new incursions of alien taxa are recorded; and to maintain up-to-date names for taxa that have been affected by nomenclatural change. In this paper, six taxa are treated, giving diagnostic descriptions and notes on their distribution. It is hoped that this information will increase general knowledge of distribution of naturalised alien taxa in Tasmania and raise community awareness of plants that have the potential to become naturalised.

Reports of new incursions, naturalised and sparingly naturalised species are welcomed by the author. Specimens and relevant collection information can be forwarded to the Tasmanian Herbarium.

MATERIALS AND METHODS

Primary sources used for this study are specimens held in the Tasmanian Herbarium (HO). Herbarium abbreviations follow Holmgren *et al.* (1990). Identifications by the author and others were checked against literature and, where available, reliably identified voucher specimens.

Voucher specimens for all species treated have been lodged in the Tasmanian Herbarium. The naturalised status of treated species is based upon field observations made by the author and others and, when available, from notes accompanying specimens.

The placement of genera in families follows the *Flora of Tasmania Online* (Duretto 2009).

Citations of synonyms are limited to names used in Tasmanian literature. Tasmanian distributions follow floristic regions proposed by Orchard (1988). Geographical origins of plants treated have been determined from various published sources. Definitions of "alien" and "naturalised" and "sparingly naturalised" have been discussed by Baker (2005).

NATURALISED TAXA IN TASMANIA

1. *Cordyline australis* (G.Forst.) Endl., Prodr. fl. Norfolk.: 29 (1833). (Laxmaniaceae)

Common name: New Zealand Cabbage Tree

Illustrations: Richardson *et al.* (2006: 8); Conran & Walsh (1994: 719); Spencer (2005: 302, pl. 8); pl. 1.

Description: Tree to 12(–20) m tall. Stems 5–10 cm diam. in young, unbranched plants, increasing to 150 cm diam. in branched, mature plants (massive trunks not seen

PLATE 1
Leaf and inflorescence of Cordyline australis.

in Tasmania to date). Bark rough, fissured. Leaves spirally arranged, clustered at the ends of branches, erect at first, becoming spreading and then deflexed at maturity, senescent leaves often remaining on the trunk; lamina narrow-linear, up to 100 cm long, 3–6 cm wide, light green with many fibrous, parallel veins; base wider than proximal half of lamina and ± stem-clasping; margin entire; apex acute, often fraying when mature. Inflorescence a large, bracteate, many flowered terminal panicle to 150 cm long. Flowers subtended by 2 dimorphic bracts; pedicels to c. 1 mm long; tepals 6, white, 5–6 mm long, free almost to the base, spreading; stamens 6, ±equal to tepals; ovary superior, globose; stigma trifid. Fruit a globose capsule, c. 4 mm diam., whitish. Seeds c. 2.5 mm long, glossy, notched on one side.

Other descriptions can be found in Moore & Edgar (1970) and Conran & Walsh (1994).

Discussion: *Cordyline* Comm. ex R.Br. is a genus of about 20 species. The majority is endemic to Australia and New Zealand with others restricted to southeast Asia, India, New Guinea, New Caledonia, South America and the Mascarenes (Conran 1998). Nine species are native to mainland Australia and one further species, *C. australis*, is naturalised. Several species, including *C. australis*, *C. fruticosa* (L.) A.Chev. and *C. stricta* (Sims) Endl. are cultivated for their "architectural" foliage (Spencer 2005). *C. australis* is immediately recognisable by its long, strap-like leaves, tree-like habit and non-serrated leaves.

Distribution and habitat: *Cordyline australis* is endemic to New Zealand where it grows in a range of generally open habitats, including forest margins, exposed hillsides, sea cliffs and close to swamps (Moore & Edgar 1970, Simpson 2000). It occurs on both the North and South Islands and on Stewart Island (Moore & Edgar 1970). In Australia, it is naturalised in South Australia, Victoria and Tasmania. In New South Wales, it has only been recorded as sparingly naturalised in the Blue Mountains area of the Central Tablelands (Wilson 2011). In Victoria, it is naturalised in rainforest near Mallacoota in the far east of the state (Conran & Walsh 1994). In Tasmania, it is widely naturalised across the state (fig. 1), much more widely than herbarium specimens indicate. Notable occurrences have been observed in and around the town of Zeehan on the West Coast, and a particularly large population (approx. 50 plants) grows in *Phragmites australis* (Cav.) Trin. ex Steud. wetland on the Tamar River.

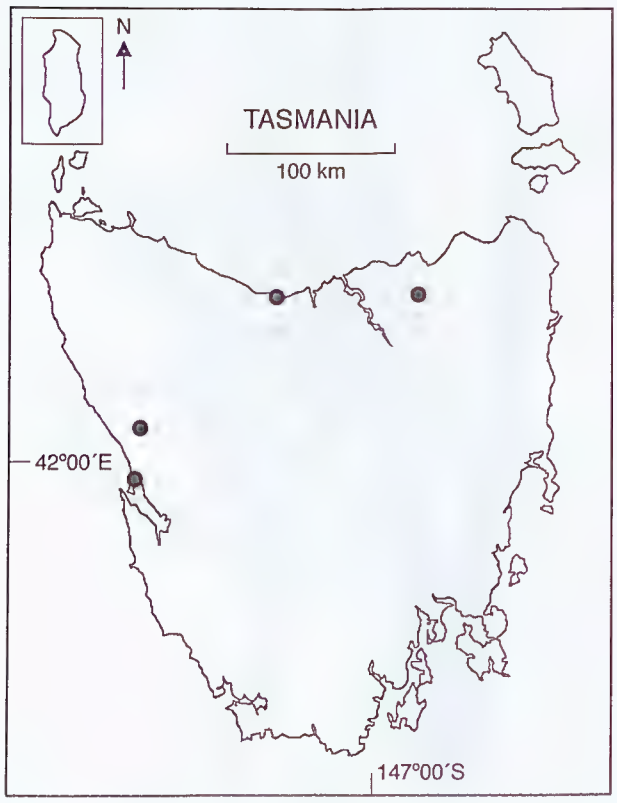

FIG. 1 — Geographical distribution of Cordyline australis *as known from herbarium specimens.*

First record: 1986, D.I. Morris.

Selected specimens examined: **TASMANIA**: *West Coast region*: Strahan, 23 Nov. 1998, *A.M. Buchanan* 15345 (HO); Zeehan Highway, 200 m east of Little Henty River, 15 Sep. 2004, *M.L. Baker* 592 *& A.M Gray* (HO). *North West region*: Don Heads, 17 Nov. 1986, *D.I. Morris* 8669 (HO, CHR, CANB, NSW). *North East region*: Little Forester River, 11 Feb. 2009, *M.L. Baker* 1956 (HO). **VICTORIA**: Wallagaraugh River, 1 km downstream from Gipsy Point settlement, 21 Oct. 1991, *N.G. Walsh* 3139 (HO, MEL, BRI, CANB, CHR). **NEW ZEALAND**: Napier, Puketitiri Road, 15 Jun. 1984, *A.M. Buchanan* 3661 (HO); North Auckland, Bay of Islands, 3 km from Pahia, 15 Jan. 1986, *J. Glasson* 97 *& M.A. Bloomfield* (HO, CHR); Manuka Bay, Port Robinson, 25 Feb. 1993, *A.M. Buchanan* 13182 (HO).

2. *Lupinus x regalis* Bergmans, *Vaste Pl. Rotsheesters*: 328 (1924). (= *L. arboreus* Sims x *L. polyphyllus* Lindl.) (Fabaceae)

Common name: Russell Lupin

Illustrations: Richardson *et al.* (2006: 263) as *Lupinus polyphyllus*; pl. 2.

Description: Erect perennial herb to 1.5 m tall. Stems sparsely sericeous. Leaves alternate, palmately compound, with 5–14 leaflets; petiole up to 170 mm long, with leaflets elliptic to oblanceolate, 30–95 mm long, 10–20 mm wide; adaxial surface glabrous; abaxial surface sericeous; base attenuate; margin ciliolate; apex acute to apiculate; stipules narrow lanceolate to narrow triangular, 5–12 mm long, up to 2 mm wide. Inflorescence a many-flowered, terminal raceme to 600 mm long; peduncle up to 140 mm long. Flowers arranged spirally to whorl-like; pedicels up to 10 mm long in fruit; calyx 5–6 mm long, densely sericeous, with upper lip shallowly 2-toothed and lower lip slightly longer and entire; corolla various shades of blue, pink, purple, yellow and white, sometimes two-toned, up to 15 mm long. Fruit an oblong, 2-valved pod, 28–40 mm long, up to 8 mm wide, densely villous, containing up to 10 seeds, style persistent in fruit. Seeds ellipsoid, slightly laterally compressed, 2–4.5 mm long, 2–2.8 mm wide, mottled brown.

Other descriptions can be found in Webb (1988) as *Lupinus polyphyllus* and Stace (2010).

Discussion: *Lupinus* L. is a genus of about 200–220 species (Spencer 2002, Mabberley 2008). It is native in North America, extending south along the Andes, with a few mainly annual species in southern Europe, tropical African highlands and southwest Asia (Phillips & Rix 2002, Mabberley 2008). Seven species are naturalised in Australia. In Tasmania, two taxa, *L. arboreus* and *L.* x *regalis*, are naturalised; *L. angustifolius* L. is regarded as sparingly naturalised as it is known only from a few small roadside populations in the north of the state. Several species are cultivated in Australia

PLATE 2
Flowering branch of Lupinus x regalis.

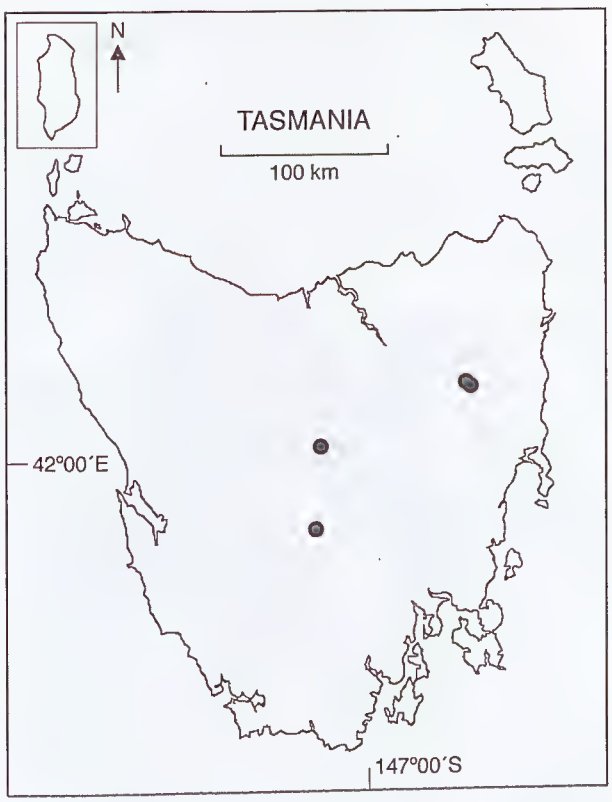

FIG. 2 — Geographical distribution of Lupinus x regalis *as known from herbarium specimens.*

as garden ornamentals, green manure crops and as broad acre crops. *Lupinus albus* L. (Albus Lupins, Broad Leaf Lupin, Lupini Beans) and *L. angustifolius* (Narrow Leaf Lupin) are grown in Tasmania as grain legumes for both animal feed and for human consumption (Knox *et al.* 2006).

Lupinus x *regalis* can be readily distinguished from other Tasmanian lupins by the large showy inflorescences that exhibit a range of corolla colours within a single population. This is in contrast to yellow in *L. arboreus* and blue in *L. angustifolius*. Plants growing at Storys Creek have flowers that are mainly whitish in colour but plants with pink and purple flowers are also present. Blue and white flowered forms are most commonly encountered in naturalised plants in New Zealand (Webb 1988).

Key to the species of *Lupinus* in Tasmania

1. Annual herb; corolla blue ..... *L. angustifolius*
1: Perennial herb or woody shrub; corolla yellow or of various colours including pink, blue and white 2
2. Woody shrub, usually growing in sandy coastal sites; corolla yellow..... *L. arboreus*
2: Perennial herb, usually growing in cool highland areas; corolla of various colours, usually pink, blue or white ..... *L.* x *regalis*

Distribution and habitat: *Lupinus* x *regalis* is a garden hybrid (or hybrid complex) with the parents being *L. polyphyllus* and *L. arboreus* (both native to North America), and possibly involving some annual species (Huxley 1999, Spencer 2002). In New Zealand, it grows in riverbeds and waste places, established locally in lowland areas, but is widespread in streams and riverbeds in montane to subalpine areas (Webb 1988). It is particularly invasive and troublesome in the braided riverbeds in the Canterbury region (Anon. 2007). In Australia, one of the parents, *L. polyphyllus*, is naturalised in New South Wales (Gardner & Murray 2002) and Victoria (Walsh & Stajsic 2007) and "questionably established" in South Australia (Barker *et al.* 2005). Images for the *Lupinus polyphyllus* entry in PlantNET (The Royal Botanic Gardens and Domain Trust 2011) and the common name used in Gardner & Murray (2002) suggest that naturalisations under *L. polyphyllus* in New South Wales are referable to *L.* x *regalis*. Examination of material held in mainland herbaria would be needed to determine the identity of all specimens currently being called *L. polyphyllus*. The same may be true in Australia, as it is in the British Isles and New Zealand that *L. polyphyllus* is rarely encountered and most records under that name are in fact *L.* x *regalis* (Webb 1988, Stace 2010). In Tasmania, *L.* x *regalis* has been recorded from a small number of locations where it has most likely persisted and spread from abandoned gardens (fig. 2).

First record: 1999, A.M. Buchanan.

Specimens examined: **TASMANIA**: *Central Highlands region*: Miena, 1 Dec. 1999, *A.M. Buchanan* 15592 (HO). *East Coast region*: Lyell Highway, just N of turn-off to Strickland, 21 Nov. 2005, *M.L. Baker* 1663 *& A.M. Gray* (HO). *Ben Lomond region*: Storys Creek township, 22 Feb. 2006, *M. Wapstra, R. Dillon & D. Rathbone s.n.* (HO); Rossarden Tip, 21 Nov. 2007, *M.L. Baker* 1839 (HO); Storys Creek, 21 Nov. 2007, *M.L. Baker* 1836 (HO, MEL, CANB).

3. *Pittosporum* Banks ex Gaertn., *Fruct. Sem. Pl.* 1: 286, t. 59, fig. 7 (1788). (Pittosporaceae)

Description: Trees or shrubs. Leaves simple, alternate, entire, petiolate, exstipulate. Inflorescence terminal or axillary; flowers solitary or in many flowered cymes; sepals 5; petals 5; stamens 5; pistil 1, ovary superior, carpels 2–5. Fruit a loculicidal capsule; seeds few to many, immersed in viscous fluid.

For a comprehensive description of *Pittosporum* in Australia see Cayzer *et al.* 2000.

Discussion: *Pittosporum* is a genus of about 100–200 species (Cayzer *et al.* 2000, Mabberley 2008) native to Australia, New Zealand, Malasia, the Pacific Islands, eastern Asia north to Japan, India, Sri Lanka and westwards to Africa. In Australia, 20 species are native and a further five species and one hybrid (*P. bicolor* Hook. x *P. undulatum*) are naturalised. Several New Zealand species are commonly grown as garden plants in Australia (e.g., *P. tenuifolium* and *P. eugenioides*) and it is such species that are the source of naturalised taxa, especially as their seeds are consumed and spread by birds. Observations have been made of Blackbirds (*Turdus merula* L. 1758) consuming seeds of *P. undulatum* (Cooper 1959). In Tasmania, one species is native (*P. bicolor*) and four species (*P. crassifolium*, *P. eugenioides*, *P. tenuifolium* and *P. undulatum*) and one hybrid (*P. bicolor* x *P. undulatum*) are naturalised. A key to all Tasmanian taxa and treatments of the four naturalised species is given below.

Key to the species of *Pittosporum* in Tasmania

1. Leaves without a prominent yellow midrib; fruit more than 6.5 mm long 2
1: Leaves with prominent yellow midrib; fruit less than 6.5 mm long ..... 3a. *P. eugenioides*
2. Fruit opening by three valves; petals maroon 3
2: Fruit opening by two valves; petals yellow with maroon markings or cream 4
3. Abaxial leaf surface persistently tomentose; flowers several in terminal umbels..... 3c. *P. crassifolium*
3: Abaxial leaf surface glabrous; flowers usually solitary in leaf axils..... 3b. *P. tenuifolium*
4. Leaves 6–13.5 cm long, 1.8–5 cm wide; leaf margins usually undulate; abaxial surface of leaf glabrous or nearly so 5
4: Leaves 1–7 cm long, 0.3–1.5 cm wide; leaf margins not undulate; abaxial surface of leaf densely hairy ..... *P. bicolor*
5. Leaf margins not undulate or slightly undulate; inflorescence with *c.* 6 flowers; petals creamy-yellow, flushed maroon (especially in bud); fruit dark yellowish-green when mature ..... *P. bicolor* x *P. undulatum*
5: Leaf margins undulate; inflorescence with up to 35 flowers; petals cream; fruit bright orange when mature ..... 3d. *P. undulatum*

3a. *Pittosporum eugenioides* A. Cunn., Ann. Nat. Hist. ser. 1, 4: 106 (1840).

Common names: Lemonwood, Tarata (Maori).

Illustrations: Spencer (2002: 18); Salmon (1992: 132–133, fig. 1–10); pl. 3A.

Description: Trees to 5 m tall (to 12 m in New Zealand). Stems glabrous. Leaves alternate, petiole up to 20 mm long; lamina elliptic, 55–130 mm long, 22–45 mm wide, sub-coriaceous; adaxial surface glabrous, glossy; abaxial surface glabrous, paler than adaxial surface; margin not revolute, irregularly undulate (sometimes only slightly); apex acute to minutely apiculate; base cuneate. Flowers in many-flowered, terminal, compound umbels; sepals 1.5–2 mm long, glabrous apart from a few hairs on the margin, erect; petals up to 7 mm long, spreading, cream; ovary pubescent. Fruit a 2-valved capsule, up to 6.5 mm long, becoming glabrous or nearly so, black at maturity. Seeds *c.* 2.3 mm diam., deep burgundy, *c.* 5 per fruit, enclosed in a papery endocarp.

Discussion: *Pittosporum eugenioides* may be confused with the more commonly cultivated and naturalised *P. undulatum*, from which it differs by having a much greater number of flowers per inflorescence and much smaller fruits that are green at first and later mature to black (compared to orange in *P. undulatum*). The leaves of *P. eugenioides* have a prominent yellow midrib and when crushed have a strong lemon smell (Salmon 1992). Forms with variegated leaves are grown in gardens in Tasmania.

Distribution and habitat: *Pittosporum eugenioides* is native to New Zealand where it is widespread in forest clearings, forest margins and along stream banks from sea level to 600 m (Salmon 1992). In Australia, it is naturalised in New South Wales, Victoria and Tasmania. In New South Wales, it is naturalised in the Upper Blue Mountains area in the Central Tablelands region where it is associated with disturbed dry sclerophyll forest (Hosking *et al.* 2007). In Tasmania, it has naturalised along forest margins, roadsides and the banks of watercourses in the East Coast and North-West regions (fig. 3).

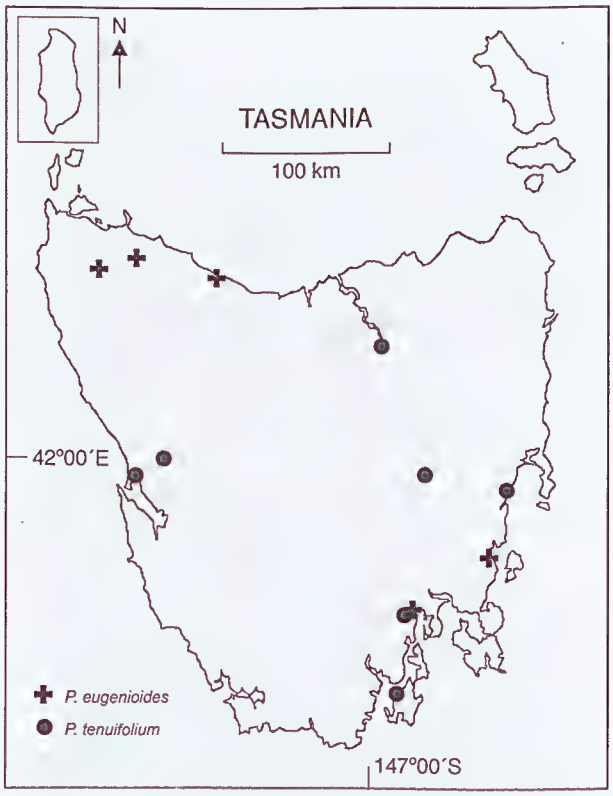

FIG. 3 — Geographical distribution of Pittosporum eugenioides *and* P. tenuifolium *as known from herbarium specimens.*

PLATE 3

Branches of (A) Pittosporum eugenioides, *(B)* P. tenuifolium, *(C)* P. crassifolium *and (D)* P. undulatum *(all bearing mature fruit).*

First record: Jan. 1996, P.A. Collier

Selected specimens examined: **TASMANIA**: *East Coast region*: Medical Building, University of Tasmania, 29 Oct. 1999, *A.M. Buchanan* 15507 (HO); behind Spring Beach, Orford. T. Higgs' property, 13 Oct. 2002, *G. Vaughan s.n.* (HO). *North-West region*: Detention Falls, 12 Jan. 1986, *P.A. Collier* 1157 (HO); Millicent Road, Mawbanna, 15 Mar. 1995, *A.M. Buchanan* 13854 (HO); Burnie, Emu River, Emu Heights, 31 Oct. 2003, *M.L. Baker* 242 (HO). **NEW ZEALAND**: Gorge Creek, East Takaka, 16 May 1965, *A.M. Buchanan s.n.* (HO); Kawakawa Bay, South Auckland, Nov. 1966, *E.N. Buchanan s.n.* (HO).

3b. *Pittosporum tenuifolium* Gaertn., Fruct. Sem. Pl. 1: 286 (1788).

Common name: Black Matipo, Kohuhu (Maori).

Illustrations: Richardson *et al.* (2006: 336); Phillips & Rix (2002: 214–5); Spencer (2002: 19); Salmon (1992: 146–147, fig. 1–10); pl. 3B.

Description: Shrubs or trees to 6 m tall (to 8 m in New Zealand). Stems sparsely pubescent when young, becoming glabrous with age. Leaves alternate; petiole 7–12 mm long; lamina elliptic to obovate, 23–55 mm long, 10–25 mm wide, thinly coriaceous, with both surfaces at first sparsely pubescent, then becoming glabrous; abaxial surface paler than adaxial surface; margin not or only slightly revolute, variously undulate; apex acute to minutely apiculate, sometimes obliquely twisted; base cuneate. Flowers usually solitary in leaf axils (also in few-flowered cymes in New Zealand); sepals *c.* 3 mm long, hairy when young, erect; petals up to 10 mm long, recurved in the apical quarter, deep maroon; ovary pubescent. Fruit a 3-valved capsule, 8–10 mm long, dark brown to black at maturity. Seeds *c.* 3 mm diam., dark reddish brown to almost black, up to 6 per fruit (up to 16 in New Zealand material).

Discussion: *Pittosporum tenuifolium* can be readily identified by having solitary flowers and relatively small leaves (up to 55 mm long) that are borne on dark brown to black stems. Various forms are grown that differ in leaf colour and variegation; Spencer (2002) lists 29 cultivars. Naturalised plants in Tasmania mostly exhibit pale green leaves without variegation.

Distribution and habitat: *Pittosporum tenuifolium* is native to New Zealand where it grows on both the North and South Islands and is common in coastal to lower montane forest from sea level to 920 m (Allan 1961, Salmon 1992). In Australia, it is naturalised in New South Wales, Victoria and Tasmania and doubtfully naturalised in South Australia. In New South Wales, a small population has been recorded growing on the disturbed margin of shrubby woodland at Leura in the Central Tablelands region (Hosking *et al.* 2007). In Tasmania, it has been recorded throughout the state, mostly in shaded, moist habitats including the banks of watercourses and in wet *Eucalyptus* forest (fig. 3). A population of numerous plants ranging in size from 1 to 4 m tall was recently recorded growing in a forest at Lunawanna, Bruny Island.

First record: May 1984, A.M. Buchanan.

Selected specimens examined: **TASMANIA**: *East Coast region*: Tirzah, at entrance on main road, 26 May 1984, *A.M. Buchanan* 3587 (HO); Waterworks Reserve, 27 Jun. 2002, *R. Glazik s.n.* (HO). *West Coast region*: Queenstown, park section of Esplanade, Queen River, 100 m S of Penghana Road bridge, 16 Sep. 2004, *M.L. Baker* 662 *& A.M. Gray* (HO); Strahan, Hogarth Falls Peoples Park, 21 Nov. 2005, *M.L. Baker* 1665, *A.M. Gray & K. Stewart* (HO). *Midlands region*: Trevallyn, Cataract Gorge, track on N side of South Esk River between First Basin and Kings Bridge, 13 Feb. 2009, *M.L. Baker* 1972 *& D. Lane* (HO). *South-West region*: Lunawanna, Bruny Island, W of Bruny Island main road, 9 Sep. 2008, *M.L. Baker* 1903, *K. Stewart & E. Schrammeyer* (HO). **NEW ZEALAND**: Waitakere Range: Scenic Drive *c.* 1 km N of Piha Road, 4 Apr. 1974, *A.E. Orchard* 4153 (HO, AK); Balls Clearing Reserve, Puketitiri, Hawkes Bay, 15 Jun. 1984, *A.M. Buchanan* 3631 (HO).

3c. *Pittosporum crassifolium* Banks & Sol. ex A. Cunn., Ann. Nat. Hist. ser. 1, 4: 106 (1840).

Common name: Karo (Maori)

Illustrations: Walsh & Albrecht (1996: 536, fig. 110e); Spencer (2002: 18); Salmon (1992: 144–145, figs 1–9); pl. 3C.

Description: Shrubs or trees to 5 m tall (to 9 m in New Zealand). Stems grey tomentose when young, becoming glabrous with age. Leaves alternate; petiole 5–15 mm long; lamina spathulate to narrow-obovate, 30–85 mm long, 12–37 mm wide, coriaceous, adaxial surface pubescent, soon becoming glabrous; abaxial surface persistently grey tomentose; margin revolute, not undulate; apex sub-acute to rounded; base cuneate to attenuate. Inflorescence a terminal umbel with up to 5 flowers (up to 10 in New Zealand); sepals 3–6 mm long, pilose on abaxial surface, spreading to deflexed; petals up to 14 mm long, recurved in the apical third, deep maroon; ovary pubescent. Fruit a (2 or) 3-valved capsule, 15–25 mm long, tomentose, pale grey-green. Seeds *c.* 4 mm diam., black, numerous.

Discussion: *Pittosporum crassifolium* can be readily identified by its large, leathery leaves that have a persistent and dense covering of grey-coloured hairs on the abaxial surface. The fruits are the largest of all the taxa in Tasmania, being large globose capsules that open by three valves, and are initially covered with an indumentum of grey hairs that gives them a pale grey-green colour. A similar species, *P. ralphii,* also a New Zealand endemic, is naturalised in wet sclerophyll forest at Katoomba in the Central Tablelands region of New South Wales (Hosking *et al.* 2007). *P. ralphii* has leaves that are abruptly narrowed to the petiole and with flat to slightly downturned margins, and fruits that are *c.* 15 mm long. In contrast, *P. crassifolium* has attenuate leaf bases, revolute leaf margins and fruits up to 20 mm long (Allan 1961, Spencer 2002).

Distribution and habitat: *Pittosporum crassifolium* is native to the Kermadec Islands and the North Island of New Zealand, where it commonly occurs at forest margins and along the banks of watercourses (Allan 1961). It was introduced to Australia as a garden plant. It is regarded as doubtfully naturalised in South Australia and naturalised in New South Wales, Victoria, Norfolk Island and Tasmania. In New South Wales, it is naturalised on the Malabar Headland, Central Coast region (Conn 2011), whereas in Victoria, it has naturalised at a few coastal sites around Port Phillip Bay (Walsh & Albrecht 1996). In Tasmania, it is naturalised on King Island where it is commonly found on sandy soils in remnant bushland surrounding the township of Currie. A small population of four plants has been recorded growing at Binalong Bay on the state's East Coast (fig. 4).

First record: Oct. 2005, K. Stewart.

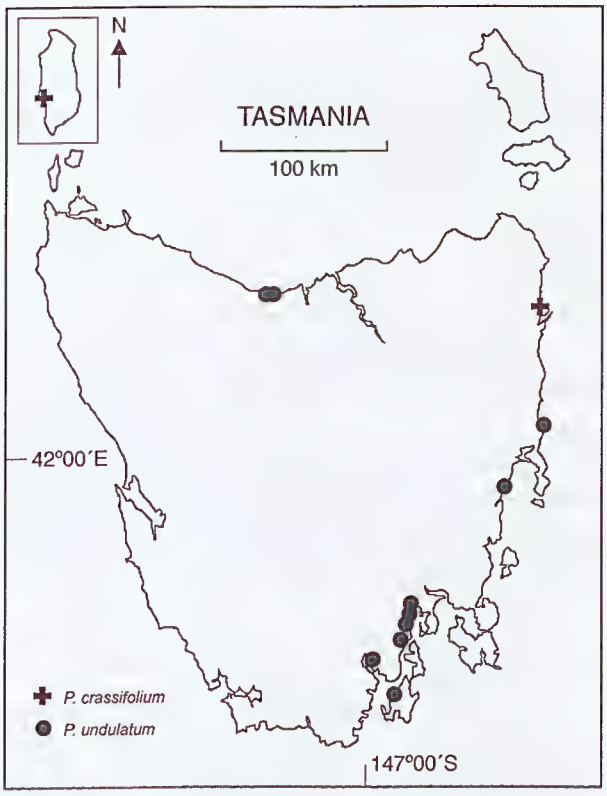

FIG. 4 — Geographical distribution of Pittosporum crassifolium *and* P. undulatum *as known from herbarium specimens.*

Specimens examined: **TASMANIA**: *King Island region*: Camp Creek Reserve, Oct. 2005, *K. Stewart s.n.* (HO); King Island, Currie, old tip site behind Beach Road, 24 Feb. 2009, *M.L. Baker* 2010, *M.F. Duretto, M. Batey & G. Batey* (HO); King Island, Currie, Beach Road, 26 Feb. 2009, *M.L. Baker* 2087, *M.F. Duretto, M. Batey & G. Batey* (HO). *North-East region*: Binalong Bay foreshore, Mar. 2008, *R. Skabo s.n.* (HO). *East Coast region*: Rose Bay, Loatta Road, 24 Sep. 2009, *M.L. Baker* 2101 (HO). **NEW ZEALAND**: Ahuriri/Westshore old inner harbour, Napier, 26 May 1986, *A.M. Buchanan* 8563 (HO).

3d. *Pittosporum undulatum* Vent., Descr. Pl. Nouv. 8:76, t.76 (1802) (Pittosporaceae)

Common Name: Sweet Pittosporum.

Illustrations: Richardson *et al.* (2006: 336); Walsh & Albrecht (1996: 536, fig. 110g); Spencer (2002: 22); pl. 3D.

Description: Trees to 13 m tall. Stems glabrous. Leaves alternate, gathered in a whorl-like arrangement at the ends of stems; petiole up to 30 mm long; lamina elliptic to ovate, 60–135 mm long, 18–50 mm wide, sub-coriaceous, both surfaces glabrous, abaxial surface paler than adaxial surface; margin not to very slightly revolute, slightly to strongly undulate; apex acute, occasionally obliquely twisted; base attenuate. Flowers in a terminal umbel-like cyme with up to 35 flowers per cluster; sepals up to 10 mm long, sparsely hairy, erect; petals up to 16 mm long, recurved in the apical quarter, cream; ovary pubescent. Fruit a 2-valved capsule, up to 14 mm long, pubescent and green at first, becoming orange, and almost glabrous. Seeds 3–4 mm diam., orange to burgundy, numerous.

Discussion: *Pittosporum undulatum* can be readily identified by its fruits that ripen to a bright orange colour. A variegated cultivar ("Variegatum") is commonly cultivated. For notes on differentiating *P. undulatum* from the similar looking species, *P. eugenioides*, see under that species.

Hybrids between *P. undulatum* and *P. bicolor* have been recorded throughout the state and are not uncommon. Such plants were not known to be hybrids when they were first described as *P. undulatum* subsp. *emmettii* W.M. Curtis (Morris & Curtis 1974). This hybrid also occurs in Victoria and New South Wales (Walsh & Albrecht 1996).

The hybrid has the following characters that differ from the parents: young leaves with scattered hairs on both surfaces; margin flat to slightly undulate. Flowers in terminal clusters of *c.* 6. Petals creamy-yellow, flushed with crimson (especially in bud). Capsule dark yellowish-green when mature.

Distribution and habitat: *Pittosporum undulatum* is native to Queensland, New South Wales and Victoria. It has been widely planted as a garden ornamental and has subsequently spread from plantings and is naturalised in Western Australia, South Australia, New South Wales, Victoria and Tasmania. In New South Wales and Victoria, *P. undulatum* is native in rainforest and sclerophyll forests and woodland from coastal areas to the highlands (Walsh & Albrecht 1996, Makinson 2002). Naturalised populations grow in wet forest and coastal scrub of southern Victoria and in forests in the Sydney region. In Tasmania, *P. undulatum* is the most common naturalised species of *Pittosporum*. It is a common environmental weed species that grows in a range of habitats but most commonly in coastal heath and dry forest bordering residential areas where it is also a common garden plant (fig. 4). It has also escaped from cultivation on Norfolk Island, Lord Howe Island (Green 1994), southern Africa, Mexico, the Caribbean, Azores, Hawaii (Weber 2003) and New Zealand (Heenan *et al.* 2002).

First record: Feb. 1974, E.B. Clayton. An undated, but most certainly earlier, specimen collected by L. Rodway exists and, given its cited location (Botanical Gardens, Hobart), it is likely that it was taken from a cultivated specimen. Records held at the Tasmanian Herbarium indicate that L. Rodway collected in Tasmania from the mid-1870s to late 1930s.

Selected specimens examined: **TASMANIA**: *East Coast region*: Bicheno, Lookout Reserve, 12 Feb. 1984, *A. Moscal* 6224 (HO, MEL); Tirzah Beach, 30 m S of mouth of Constable Gully Creek, 4 May 1984, *D. Ziegeler s.n.* (HO). **SOUTH AUSTRALIA**: Stirling. W side of Goulds Road, *c.* 0.22 miles [0.4 km] from its junction with Pomona Road, 20 Mar. 1957, *Booth* 54 (HO, NSW). **NEW SOUTH WALES**: *c.* 1 mile SE of Wolumla Princes Highway, Bega District, 17 Mar. 1964, *R. Schodde* 3486 (HO, NSW); Victoria Falls, Mt Victoria, 24 Mar. 1965, *E.F. Constable* 5721 (HO, NSW, MEL). **VICTORIA**: Blackburn, Blackburn Lake Sanctuary, 22 Sep. 1981, *T.B. Muir* 6635 (HO, MEL).

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(accepted 1 November 2011)

THE LICE (INSECTA: PHTHIRAPTERA) OF SHORT-TAILED SHEARWATERS, *ARDENNA TENUIROSTRIS*, IN BASS STRAIT, TASMANIA

by Janine E. Box and Catherine E. Meathrel

(with two tables)

Box, J.E. & Meathrel, C.E. 2011(9:xii) The lice (Insecta: Phiraptera) of Short-tailed Shearwaters, *Ardenna tenuirostris*, in Bass Strait, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 145: 35–38. ISSN 0080-4703. Department of Environmental Management and Ecology, La Trobe University, Wodonga, Victoria 3690, Australia (JEB*, CEM). *Author for correspondence. Email: neens_02@hotmail.com

Lice from 30 adult and 60 pre-fledgling chick Short-tailed Shearwaters, *Ardenna tenuirostris*, on Great Dog Island in Bass Strait, Tasmania, were sampled using the fumigation method. Five species of chewing lice (Phthiraptera: Ischnocera and Amblycera) were collected, including: *Naubates harrisoni, Halipeurus diversus, Trabeculus hexakon, Austromenopon paululum* and *Ancistrona vagelli,* none of which were new species records for this seabird. The highest rates of louse infestation were on pre-fledgling shearwater chicks.

Key Words: lice, Phthiraptera, procellarid, Tasmania, shearwater, *Ardenna tenuirostris*.

INTRODUCTION

There is a paucity of research into the louse fauna of Short-tailed Shearwaters, *Ardenna tenuirostris* (Temminck, 1835), despite this species being one of the world's most studied seabirds (Bradley *et al.* 1991 and references therein). Research has been undertaken on these shearwaters at their breeding grounds in Bass Strait, Tasmania, since 1947 (Bradley *et al.* 1991). As Short-tailed Shearwaters are long-lived, with an estimated average longevity of 38 years (Skira *et al.* 1985), they may offer a long-term host potential to host-dependent ectoparasites (i.e., lice) (Crompton 1997). Also, with approximately 23 million shearwaters breeding in burrows in dense rookeries on the islands and headlands of southern Australia, from southern New South Wales to Tasmania and from Victoria to Western Australia (Marchant & Higgins 1990), there may be the potential for increased transmission of ectoparasites between individual birds. Increased infestation rates by lice have been shown in colonial living birds. For instance, Rózsa *et al.* (1996) found an increase in louse infestation on Colonial Rooks, *Corvus frugilegus* Linnaeus, 1758, as compared to the territorial Hooded Crow, *Corvus corone cornix* Linnaeus, 1758.

Short-tailed Shearwaters undertake an annual trans-equatorial migration to the Bering Sea for the austral winter (Serventy 1967), and so may act as vectors for the transmission of parasites across hemispheres (Lopez *et al.* 2005, Price *et al.* 2003).

There are three publications that list the lice of Short-tailed Shearwaters. Green & Munday (1971) were the first to document the ectoparasites of Tasmanian fauna, albeit from personal communications – no published literature was cited. Twenty years later, Green & Palma (1991) listed the lice of Tasmania's vertebrates. They essentially used Green & Munday's (1971) list of lice on shearwaters and added *Austromenopon paululum,* listed as *Austromenopon* sp. in Green & Munday (1971).

Price *et al.* (2003), in their checklist of the chewing lice (Phthiraptera) of the world, also listed the lice of Short-tailed Shearwaters. Included in this list were two louse species, *Naubates harrisoni* (Bedford, 1930) and *Ancistrona vagelli* (Fabricus, 1787), not mentioned in Green & Munday (1971). As part of the long-term research into Bass Strait's Short-tailed Shearwaters, this study aimed to confirm their current louse fauna, detailing the specific location, and collection method, to fill a gap in the primary literature.

METHODS

This research was conducted on Great Dog Island (40°15'S, 148°15'E; Skira & Brothers 1988), located in the Furneaux Group of islands in Bass Strait, off the northeast coast of Tasmania during austral summer 2009/2010. Lice were sampled as part of the long-term examination of the breeding success of Short-tailed Shearwaters on this island (Bradley & Meathrel 2006). Research was conducted over two periods corresponding to the Short-tailed Shearwater's breeding season: in December 2009 immediately after the egg-laying period (25–28 November), and in April 2010, just prior to the chick fledging period at the beginning of May (Serventy 1963).

Lice were collected from randomly chosen shearwaters, 30 adults (December) and 60 pre-fledglings (April), using the fumigation method as outlined in Furness & Palma (1992) and Steele *et al.* (1997). Birds were removed from their burrows by hand and placed inside a plastic bag containing a cotton ball soaked with trilene (trichloroethylene), an anaesthetic. The head of the bird remained out of the bag with nares directed into the wind to ensure the bird did not inhale the trilene. The bird was fumigated in the plastic bag for a total of one minute to minimise stress. After one minute the bird was returned to its burrow and the ectoparasites were collected from the plastic bag and cotton ball and placed into a labelled zip lock bag. The ectoparasites were then removed from the zip lock bag and preserved in vials containing propylene glycol. All work was conducted under La Trobe University Animal Ethics Committee Licence AEC05/15 (W) and Tasmanian Department of Primary Industries, Water and Environment Permit to take Wildlife for Scientific Purposes FA 09118 held by CEM.

RESULTS AND DISCUSSION

All species of lice that inhabit birds belong to the suborders Amblycera and Ischnocera (chewing lice) in the order Phthiraptera (Price *et al.* 2003). Among the ca. 4000 species of chewing lice from birds distributed worldwide (Price *et al.* 2003), only five species, from the two suborders, were collected from Short-tailed Shearwaters on Great Dog Island (table 1). All of these lice are pan-global (Price *et al.* 2003) and have been previously reported on Short-tailed Shearwaters and other procellarids (table 1).

The incidence of louse infection is shown in table 2. Infestations with ischnocerans were more common than with amblycerans, particularly on pre-fledgling shearwater chicks. Low infestation rates, with some birds harbouring no lice, are common in some procellarid species (Gomez-Diaz *et al.* 2008). Gomez-Diaz *et al.* (2008) found infestation rates from 20.2% sampled birds infected to 100% sampled birds infected.

Ischnoceran lice feed on the keratin of feathers and dermal debris (Marshall 1981, Clayton *et al.* 1992). They have tarsal claws as morphological specialisations for attachment to feathers and are rarely found on the skin of birds. Amblyceran lice, however, are more mobile than ischnoceran lice and will freely roam upon the host's skin and readily drop from their host. They feed on dead dermis, feathers and dried blood around wounds. These differences in louse morphology and feeding mode may explain the higher infestation rates of ischnoceran lice on pre-fledgling compared to adult shearwaters. Pre-fledglings have actively growing, highly vascularised down (Warham 1996) which may be preferential to ischnoceran lice compared to the hard central shaft feathers of adults.

The primary defence of birds to ectoparasite infestation is preening (Warham 1996), a learnt behaviour which can strip ischnoceran lice from the feather shaft and remove amblyceran lice from the skin, reducing infestation rates. Pre-fledgling chicks are ineffective at preening compared to their parents. This may result in the higher infestation rates of lice on pre-fledglings compared to adult Short-tailed Shearwaters. Such a result has been shown in Brown Pelicans, *Pelecanus occidentalis* Linnaeus, 1786 by Eggert & Jodice (2008). The higher infestation rates on chicks may also be explained by the burrow-nesting behaviour of Short-tailed Shearwaters. Extraction of birds from their burrows by hand may mean that amblyceran lice simply drop off the host as the bird is extracted from the burrow, whereas ischnocerans remained attached. When feathers, on which ischnoceran eggs, nymphs and adults are attached, are shed and lost, the infestation rates of adults are reduced compared to burrow-bound chicks.

This research provides the first documentation on the location, collection method and date of collection of the lice of Short-tailed Shearwaters. Price *et al.* (2003) believe that this information is important for the further understanding of the factors affecting the distribution of lice.

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TABLE 1
Lice recorded from Short-tailed Shearwaters and other Tasmanian shearwaters

Sub-order	Family	Species	Hosts (references)
Ischnocera	Philopteridae	*Naubates harrisoni*	Palma & Pilgrim 2002; Price *et al.* 2003; this study
Ischnocera	Philopteridae	*Halipeurus diversus*	Green & Palma 1991; Price *et al.* 2003; this study
Ischnocera	Philopteridae	*Trabeculus hexakon*	Green & Palma 1991, this study
Amblycera	Menoponidae	*Austromenopon paululum*	Green & Palma 1991, Price *et al.* 2003, this study
Amblycera	Menoponidae	*Ancistrona vagelli*	Price *et al.* 2003, this study

Table 2
The incidence of louse infection on Short-tailed Shearwaters from Great Dog Island, austral summer 2009/10

Louse species	Adult (n=30)	Pre-fledgling (n=60)
Naubates harrisoni (I)	1	20
Halipeurus diversus (I)	4	26
Trabeculus hexakon (I)	2	0
Austromenopon paululum (A)	2	8
Ancistrona vagelli (A)	1	1

(I) = *Ischnocera*, (A) = *Amblycera*

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GRASPING THE NETTLE — THE TASMANIAN GEOLOGICAL SURVEY'S WORK ON LANDSLIDES, 1971–1988

by Peter Charles Stevenson

(with four text-figures and five plates)

Stevenson, P.C. 2011 (9:xii): Grasping the nettle — the Tasmanian Geological Survey's work on landslides, 1971–1988. *Papers and Proceedings of the Royal Society of Tasmania* 145: 39–50. ISSN 0080-4703. 135/319 Macquarie Street, South Hobart, Tasmania 7004, Australia. Email: psteve135@gmail.com

The state of Tasmania had suffered from its foundation from landslides. A policy of limited compensation for property loss had been established in the 1960s as insurance was not available but landslide damage had continued and the compensatory policy had to be abandoned. The Tasmanian Geological Survey worked on this problem mainly in Northern Tasmania and devised a system of advisory zone maps to control building development, followed by legislative controls. Some comments are made on the social impact of these measures. The period from 1971 to 1988 is described as being the main period of innovation. A selection of the originating reports is referenced, and a site for the whole corpus is given.

Key Words: landslip, landslide, legislation, Tasmania, Tasmanian Geological Survey.

INTRODUCTION

Landslides are a recognised problem throughout Tasmania. Some parts of the state are particularly vulnerable, and amelioration of such risk came under the purview of the Engineering Geology Section of the Geological Survey of Tasmania. During the period 1971–1988, a coordinated effort to reveal the causes of landsliding and to devise a strategy to counter them, was instigated by the government of the day under the leadership of the Premier, the Hon. Eric Reece, in response to considerable loss of houses in the preceding years.

This paper records that work, the vast majority of which was undertaken in the areas of immediate need, notably the Tamar Valley and the North-West Coast of Tasmania.

The approach was based firstly on the geology as revealed by regional mapping, then on geomorphology and on a study of the clay materials involved as revealed by soil mechanics. The structures of slides were sometimes elucidated by geophysical means. A landslide-risk-class system was then set up and together with resulting maps and finally legislative additions to the *Local Government Act 1962* control could be exercised over building development.

Development of the system involved face-to-face discussion with members of the public and with local government councils. This approach was valuable in that it removed the usual criticism that public servants were making decisions affecting the public without having shown that the basic research had been done. It also served as a strict check on the work in the field done by the Geological Survey officers.

GEOLOGY

The surface geology was available from the regional mapping of the Launceston (Longman *et al.* 1964), Pipers River (Marshall *et al.* 1965), Beaconsfield (Gee & Legge 1971), Devonport (Burns 1963), Burnie (Gee *et al.* 1977) and Table Cape (Gee 1966) sheets of the Geological Atlas One Mile Series issued by the Department of Mines. These indicated the presence of Tertiary sediments known to be involved in landsliding, as well as the presence of Tertiary basalt that was often implicated, either as a triggering aquifer or in weathered condition as actively sliding material (Blake 1961, Jennings 1964a) (pl. 1).

The stratigraphic and lithologic relations within the Tertiary sediments of mainland Tasmania were not known in any detail (see Burrett & Martin 1989) and appear to remain so to this day, owing to their complexity, and their labile nature, leading to a very poor outcrop expression. This property did not disadvantage the geomorphic studies as each landslide exposure had to be treated as a unit without other than a general reference to other occurrences. The labile clay sequences were those involved in landsliding, while the gravelly or sandy members were not, except as intercalated aquifers.

THE NATURE OF LANDSLIDES

The terms landslip and landslide are synonymous, the former being English practice and the latter American. The latter is preferred here as a "slip" appears to imply a minor feature which may nevertheless have serious consequences.

PLATE 1
The Batman Slide (41.21°S; 146.92°E) in Tertiary clays, water being fed from overlying Tertiary basalt.

The phenomenon had been extensively covered in the literature, but the works of Zaruba & Mencl (1969) and of Schuster & Krizek (1978) are conspicuous. The publications of Chowdhury (1978) and Walker & Fell (1987) are also notable and represent an extensive literature. All these works indicate the terms employed in description of materials, of geometry, of climatic setting and of all types of slope movement. Recognition of movement and the details of field investigation, the measurement of strength properties and methods of stability analysis are all covered in detail, with many relevant examples. This background will be assumed in the present account.

The Tasmania landslides are characterised by slow movement, usually no more than one metre per month, on slopes as little as 6° rising to as much as 14°, and are described as slow earthflows. Rotational slides are only seen in early stages of movement, but these develop into translational slides. Collectively these may be called slump earthflows. They have been described as "slow disasters" by householders whose property is threatened or destroyed.

PREVIOUS WORK

The earliest work on landslides in Tasmania appears to be that of Friend (1849), and dealt directly with the problem, rather than merely mentioning landslides as a peripheral topic. Friend's appreciation of the problem has a remarkably modern look, and one would wish to know more of this naval officer and Fellow of the Royal Society, who subsequently became Port Officer in Hobart (*Hobart Town Gazette* 1838).

Friend recognised that cultivation of steeper slopes and removal of trees might lead to instability (pl. 2), that the opening of fissures would increase the access of water to the slide plane, that downward movement of the slide mass would cause the toe area to rise up, and that control might be established by judicious drainage of the land above the slide.

Ingles (1974) described the Australian incidence of landsliding, and gave some account of Tasmanian examples, but other local accounts such as Johnston (1874, 1888), Carey (1946) and Kershaw (1955, 1958) have very little to say on the subject. Johnston uses the term "wanton unconformity" ambiguously when describing the Tertiary sediments of Windmill Hill and did not make clear whether the term applied stratigraphically or to the outcrop pattern.

When we turn to Geological Survey records, the field is much richer, but this was the result of more or less *ad hoc* studies occasioned by separate events until 1971, when the systematic studies which are the core of this paper began. All reports by the Tasmanian Geological Survey are available online from the Mineral Resources Tasmania (MRT) website (www.mrt.tas.gov.au) using the "Document Search" facility with the keywords landslip, landslip zone map, landslip active and dormant landslip.

Nye (1931a, b, c) was concerned with Groom's Slip and the Lonah Slip (fig. 1). These are located on the coast between Penguin and Ulverstone. Groom's Slip reappears several times in the records and as a persistent phenomenon will continue to do so. Nye related how there had been movements of Groom's Slip "28 years ago" and that draining work was done until defeated by "slurry". It seems likely that this landslide has afflicted transport movement in the area for much of the European settled life of Tasmania. Because it affects the railway as well as the road it attracts close attention (pl. 3). Nye showed that the landslide is

PLATE 2
Incipient Head Scarps in a new slide at White Hills (41.53°S; 147.26°E).

translational and moves on a dolerite (*sic*) planar surface, with some accumulation at the toe. As this is just above sea level, instability is maintained by the constant erosion of the toe by the waves. A sand layer was implicated as the source of water which drove the movement, and that the use of drains would have to wait until movement stopped.

Blake (1958) had to deal with a landslide away from the principal locus of concern. The slide at Bream Creek had interrupted a rural road over many years and consisted of basalt-derived slope deposit, and was driven by springs issuing from the basalt upslope. Drainage or diversion of the road was suggested.

Burns (1957) considered unstable slopes at Kelcey Tier near Spreyton (fig. 1), again away from the Tamar and the North-West Coast. These posed a potential threat to the projected water pipelines. Burns considered the geology in

PLATE 3
Groom's Slip (41.12°S; 146.11°E): view from the toe looking up the slip. The railway and road are shown crossing the slip.

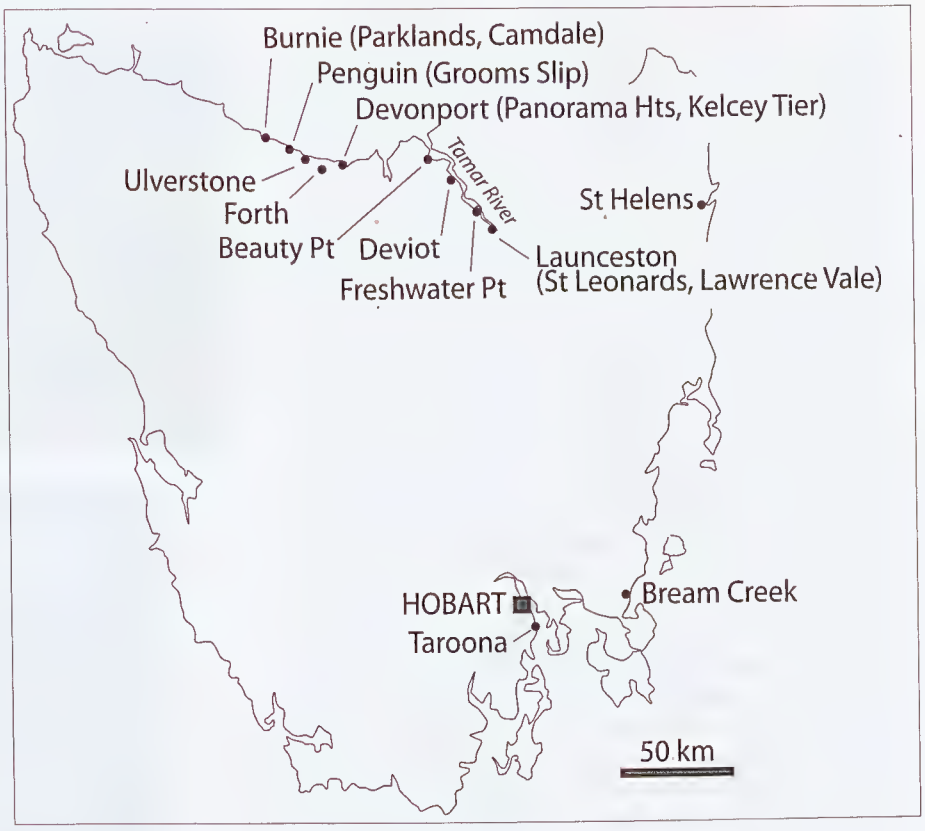

FIG. 1 — Map of Tasmania showing principal locations referred to in the text.

some detail; then, when looking at the stability of the slopes, found that geomorphology provided the most useful guide. He recognised four types of instability, and provided most useful analyses that became of importance in subsequent investigations.

Burns (1959) dealt with pipeline routes again in northern Tasmania and commented on unstable slopes, then Hughes (1959) described landslides at Burnie (fig. 1) in basalt-derived soils, and pointed to increased access of water to the site from development activities as being the precipitating factor. He recommended that surface drains be lined and that councils should exercise caution in granting subdivision permission on the slopes of basalt hills.

Blake (1961) examined the landslides of longstanding at Beauty Point (fig. 1) and showed that the presence of a basalt aquifer overlying plastic clay is a recipe for instability that is later revealed as very common. He mapped active sliding and suggested drainage of a swamp formed in a slide-caused reversal of slope.

Hughes (1960), in a report on a meeting held in Launceston Town Hall in relation to the Lawrence Vale Landslip (fig. 1), revealed that it was the site of the destruction of a number of houses in the 1950s. Dr G. Aitchison of the CSIRO and Mr E. Gill of the Victorian Museum were present. This expert intervention had been arranged by Prof. Sam Carey and was to consider the conduct and costs of a general survey of the parts of Launceston underlain by Tertiary sediments. The meeting was abortive as the costs were considered too high, no further work was done and the project was abandoned.

Jennings (1962) re-examined instability at Parklands, Burnie, and incorporated the work of Burns & Gee (1962). Landsliding had destroyed an urban street, disrupted water supply, drainage and communication services, as well as blocked the Bass Highway. Causes were numerous including the usual abundance of uncontrolled access of water to the site, deficient drainage, construction works loading the slope and trenches acting as recharge areas. Disruption of roads was of major concern as illustrated in plate 4.

Jennings (1964a) took up the tale of Beauty Point instability, and enlarged on the work of Blake. He provided maps of the geomorphology, suggested restricted areas for building and recognised that unwise development is a contributing cause of instability. Controls on subdivision were required. Jennings (1964b) made detailed recommendations, and a general review was attempted of slope problems in the Burnie area. This report is seminal, and forms a foundation for much of the subsequent landslide work in Tasmania.

Matthews (1964a, b) and Jennings (1964b), working on the North-West Coast, must be credited with the concept of zones drawn on maps to limit development in landslide-

PLATE 4
Pleasant Hills (41.36°S; 147.01°E) showing the disrupted road surface toward the toe area in Tertiary clays.

prone areas on the basis of geology, geomorphology and slope. This concept was adopted and extended during the succeeding systematic survey. Jennings (1969a) then returned to Beauty Point, and suggested precautions to be observed by the council, in the siting of houses, and the installation of more effective drains.

Stevenson (1969) described a mud spring and a landslide at Deviot (fig. 1). The spring showed the behaviour of groundwater where water-filled gravels and clay horizons are in contact, and the landslide in similar geology nearby showed the disruptive effects of excess groundwater in sensitive conditions. The shape of the slide and the effects of drying, wetting and shrinkage on the exposed clays were described, and the remarkably low angle of slope to induce movement was indicated.

Jennings (1969b) visited the Lawrence Vale Landslip Area which was the subject of the *Lawrence Vale Landslip Act 1961*. He described the tension cracks in the landslide as being water-filled, and stated that other houses were threatened. He considered that the landslide might extend northward (Jennings 1969b). He recommended the installation of herringbone counterfort drains, and that a close eye be kept on further movements. Jennings & Stevenson (1969) expanded on this report and revealed further details of the geology. Actual movement was seen in opened trenches, and the landslide was seen to be purely translational. The drainage and support measures being taken were confirmed.

Stevenson (1971b) described some zoning at Camdale and added some thoughts on how to go about a decision on land stability. Stevenson (1972c) investigated the 1969 reactivation of the landslide at Beauty Point, which resulted in 12 houses and a police station being destroyed, demolished or removed due to extensive damage, and Jennings (1972) investigated the major landslide problems developing in Tertiary sediments at Parnella, near St Helens (fig. 1).

These studies provided the background on which the Engineering Geology Section began its systematic study of landslides and was used to guide the systematic study.

The Government had provided some compensation for landslide loss by the *Lawrence Vale Act 1961*, the *Beauty Point Act 1970*, and subsequent extensions. Even though landslide risk is uninsurable, this approach could not continue as more and more landslide hazards were revealed.

The study was therefore authorised by the Premier of the day, the Hon. Eric Reece who was also the Minister of Mines. I have been unable to find a written instruction, but was present when Mr Reece, inspecting the landslides at Freshwater Point on 16 March 1972, said that "we must grasp the nettle".

THE SYSTEMATIC SURVEY

Some 800 landslides of various sizes and activity had been recognised in the Tamar Valley, and a similar number on the North-West Coast, though an inventory of individual landslides was not compiled. It was therefore with a wholesale "walkover" of the Valley and of the Coast that the study began. All geologists in the team had to become familiar with the examples previously described and as new geologists joined the work they were expected to take this tour. The various skills of the Engineering Geology Section provided an augmentation of techniques utilised as the survey developed; for example, the addition of soil mechanics, test pits, geophysics and stability analyses.

PLATE 5
A, B. Two views of Side Shear of the St Leonards Slide (41.45°S; 147.21°E).

The 22 examples that follow are a selection from 221 that became technical reports and unpublished reports within the Survey. They are chosen to outline the methods that became the genesis of the Landslide Risk System, and the total number is available online at www.mrt.tas.gov.au

As the number of the reports rose (they totalled nearly 300), further specific public enquiries were dealt with by individual correspondence, and are not quoted here, but are recorded in the CARS database, a correspondence database held by MRT.

Stevenson (1971a) was concerned with a proposed subdivision near Penguin. The geology was examined and revealed that a grey clay horizon is present underlying basalt which caps the slope. This situation was described as "well known in basalt areas in Northern Tasmania", and was further revealed by four trial pits excavated by backhoe. It was concluded that the grey clay poses a minor hazard to road construction, but that subdivision and the introduction of additional water could produce more extensive failure

of the hill slope. Some restriction of subdivision and care in the development of the remainder was recommended.

Elmer (1971) at Freshwater Point, in the middle Tamar, showed that small landslides had already occurred, and recommended that trial pits should be opened in an attempt to reduce the suspect area, but in general houses should be restricted to the flatter areas away from the crest of the slope. Stevenson (1972a) then described a landslide that was threatening two large water storage tanks of the Tamar Water Supply at St Leonards, outside Launceston (fig. 1, pl. 5A, B). The landslide was first reported in 1968 and the current study was a visit to determine the state of the slide. It appeared to have formed as a result of leakage from a valve pit close to the tanks, but on this occasion it showed signs that it had stabilised, desiccated and then several wet seasons had remobilised and extended it. In addition, it had eaten upslope closer to the base of the tanks. Remedial stone-filled drains had been disrupted by the further movements, and the planting of high transpiration trees was suggested.

Stevenson (1972b) provided the latest of three reports on a subdivision at Panorama Heights, Devonport (fig. 1). This report was supported by soil mechanics tests conducted by the Public Works Department (Kowaluk 1972 as an appendix to this report). Here, a significant step in investigation was taken with the use of calculated stability analysis. A pessimistic view as to the viability of the subdivision was the conclusion, and subsequently Landslip Zones were proclaimed.

Matthews (1972) reported on an adjacent subdivision, but with markedly different geology, and as determined from some 15 test pits, most of the area was assessed as suitable for subdivision after drainage and siting precautions were taken.

Stevenson (1974) re-examined Groom's Slip. Seismic refraction, proline auger drilling and soil mechanics, and the installation of piezometers were recommended, whilst Matthews (1974) continued the series of reports on the landslip at St Leonards.

Leaman (1974) summarised geophysical methods appropriate to landslide studies and gave some examples. This enlarged the detail available on some difficult slides.

Knights (1975) provided a detailed soil mechanics study of typical Tamar clays. Atterberg limits, strength sensitivities and X-ray diffraction studies enlightened work on specific occurrences elsewhere. Knights & Matthews (1977) then produced a report that constituted a major advance, occasioned by another reactivation of the movement at St Leonards. Detailed topography, drilling of some 27 holes for the location of water-bearing horizons, the installation of movement detectors in the boreholes, the determination of soil mechanics parameters and clay mineralogy, a study of groundwater chemistry, and an evaluation of geophysical methods were all included. A Bishop slope analysis was attempted, and recommendations for remedy were made.

The report of Donaldson (1977) opened a new field of investigation at Taroona, a suburb of Hobart, outlining a large, very slow moving slide involving the main road, the primary school, the high school and numerous dwellings.

Knights (1977a) continued work in the Tamar Valley using stability analysis to show "very tenuous" stability in movement at McEwan's Road, Tamar. She also re-examined the Lawrence Vale landslide, employing seismic refraction and drilling, and showing the presence of a pressure aquifer (Knights 1977b). Recommendations included tree planting and the installation of additional counterfort drains.

Knights (1977c) provided a piezometric study of aquifers and related clays over an extended period of wet and dry seasons at Lawrence Vale.

In the light of previous investigations, guidelines were offered for studies in stability and swelling soil conditions by Stevenson (1978a). Stevenson (1978b) further provided a work-in-progress report showing the current methods .This report encapsulated the entire philosophy for risk zoning, and drove the work which is the subject of the present paper. Details were given of the construction of the zones and comments on confrontations with objectors were offered. Stevenson (1978c) extended definitions of the Risk Zones were offered to clarify some doubts.

Sloane (1979) re-examined neglected failures in Tertiary sediments at St Helens. Although known before, this became a new area of investigation. Drainage, vegetation and marine erosion protection works were suggested.

A period of little innovation followed: reporting was largely confined to correspondence as mentioned in the CARS database, but work continued unabated. For example, Moon (1984a) described the use of a hand calculator to perform Bishop analysis and gave the code for it. This gives an idea of the sophistication of calculation methods of the time. Moon (1984b) provided a new consideration of the conduct of slope stability assessments whilst Weldon (1987) gave an account of a Bishop slip circle analysis programmed on a micro-computer. Again this is a comment on the methods of the time.

These selected reports indicate the evolution of methods, and include trial pits, soil mechanics sampling, piezometer installation and recording, slide plane depth determination by various means, geophysical surveys including resistivity, seismic refraction, induced vibration for additional data, slide movement measurement by repeated survey and movement monitors, and calculated stability analysis

THE EVOLUTION OF THE RISK MAPS

It should be admitted that the term "risk" in this context is a misnomer and should in modern practice be denoted "susceptibility". These maps do not include a concept of frequency or temporal likelihood so are not true "hazard" maps in the modern use of the term. However, the term "risk" is so entrenched in the use of these maps that it will be retained in this paper.

In the light of the experience detailed above it was an easy decision to adopt this system. Five zones were set up (Stevenson 1975a), applicable to the Tamar Valley (figs 2, 3). Other areas were not comprehensively covered in this way but the concept was used widely. The five zones were :

Zone 1–Stable ground on hard rocks. No abnormal problems or risks. This zone was generally on dolerite;

Zone 2–Stable ground but on soft rocks. Strict adherence to existing building code. This zone was generally on Alluvium or on Tertiary sediments of little topographic expression; with slopes less than 6°.

Zone 3–Potential landslip areas. Building methods in accordance with special building regulations. This zone was generally on Tertiary sediments or related slope deposits having a ground slope greater than 6°;

Zone 4–Old landslips and adjacent areas. No building permitted pending further studies; and

Zone 5–Active landslip. No building permitted.

Many clarifying comments were appended to these

FIG. 2 — The Tamar River valley showing risk zones. Risk zones: ***V****, Active landslips and adjacent areas. No building without specialised investigation and design.* ***IV****, Old landslips and adjacent areas. No building without specialised investigation and design.* ***III****, Potential landslip areas. Building methods in accordance with a special code.* ***II****, Stable ground but on soft rocks. Strict adherence to existing building code.* ***I****. Stable ground on hard areas. No abnormal problems or risks.*

FIG. 3 — The Tamar River valley showing risk zones. Key and location map as for figure 2.

definitions. One became of major significance. The word "potential" was used by real estate agents as a laudatory term, as in "this land has great potential", whereas in our context it was pejorative, and caused confusion.

These zones were depicted on maps at the scale of four inches to the mile (1:15840) as these were the best available, and reproduced as dyelines (figs 2, 3), and were freely available on request. Though crude, these maps served for many years, summarising the findings of the detailed field investigations, and they formed a basis for detailed discussions with councils and members of the public. There was a risk of the maps being over-interpreted, but the scale was such that this did not occur often, and the risk was obviated by the usual field visit of the geologist, when features on the ground were pointed out. The Survey provided a consultant service to councils, authorities and the public, at first without cost, but subsequently at a nominal cost.

The landslide maps produced by the Geological Survey were used by some authorities and interested parties in an informal process to prompt interpretation by a Survey geologist and usually a site inspection. There was no legislative requirement for these advisory maps to be considered in the planning process.

Because the Tamar Valley was under constant re-examination, mistakes were readily noticed. Such cases were very few and minor, a tribute to the accuracy of the initial appreciation of the problem. The same remarks can be applied to the maps of the North-West Coast.

THE CHANGES TOTHE LOCAL GOVERNMENT ACT

The Government had provided some protection from landslide loss by the *Lawrence Vale Act 1961*, and the *Beauty Point Act 1970*, with subsequent extensions. As has been indicated, this compensatory approach could not continue as more and more landslide hazards were revealed.

In order to give teeth to the application of restrictions implied in the Zone definitions, an amendment (Section 431A) to the *Local Government Act 1962* was brought in which empowered the Director of Mines to recommend the proclamation of zones where special conditions of building would apply. These were called "A" and "B" Landslip Areas and were prescriptive as opposed to the mapped Risk Zones which were advisory (fig. 4).

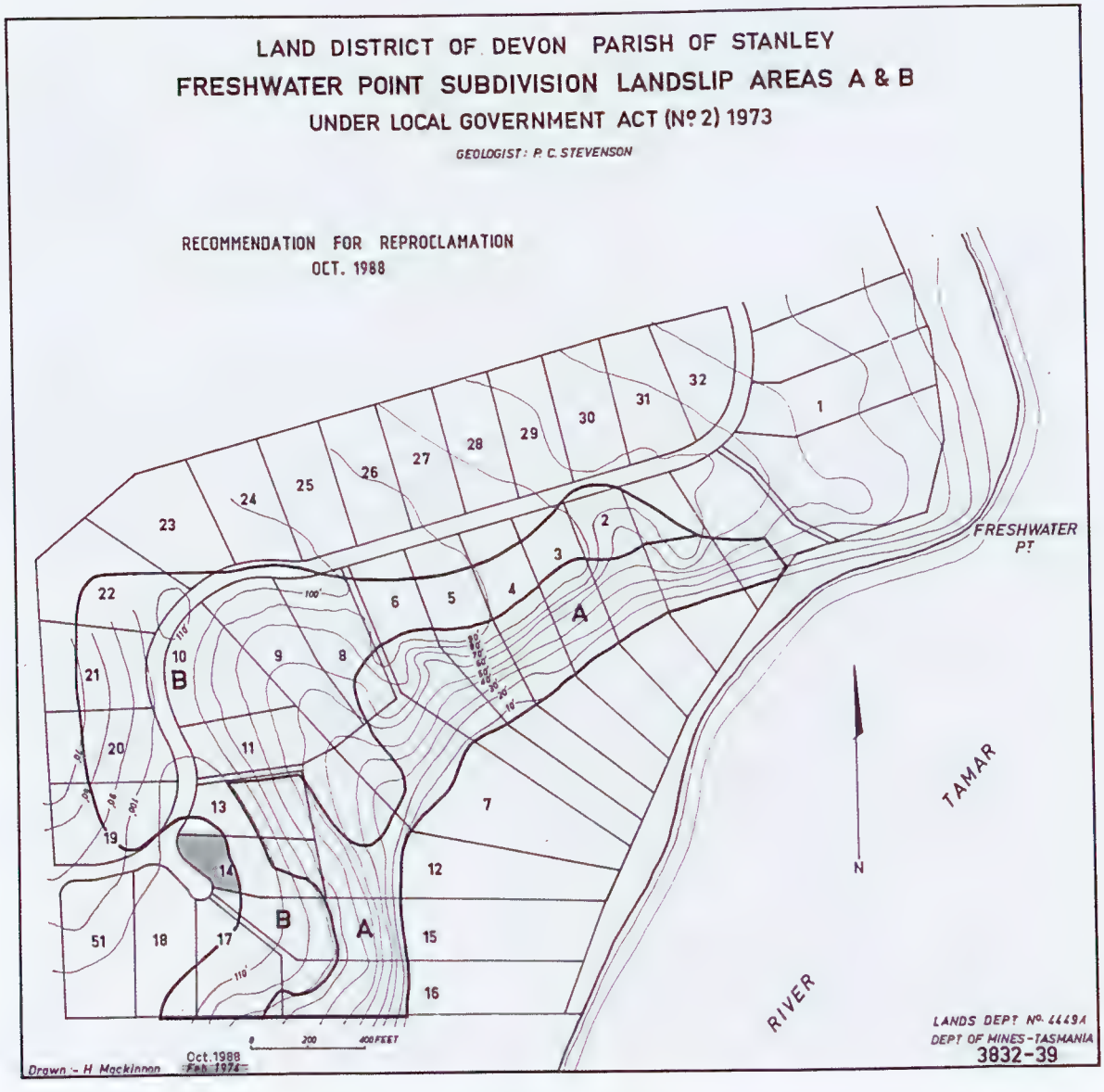

FIG. 4 — Freshwater Point Subdivision, Landslip areas A and B.

Landslip "A" areas were broadly areas where landsliding was apparent, and adjacent areas into which the slide could, in the opinion of the geologist, extend. Landslip "B" areas were those where a threat of movement was thought to exist, but the threat could be reduced by suitable building methods. Landslip "B" areas also served the purpose of buffer zones to the Landslip "A" areas, so as to prevent inappropriate practices in the Landslip "B" area affecting the stability of the Landslip "A" area. There was some correlation with the 5 and 4 Zones of the risk maps, but this was not explicit, having been arrived at independently. These proclaimed Landslip Areas were defined by a map.

These provisions of the *Local Government Act 1971* were subsequently amended and expanded in the *Local Government Act (No2) No 96, 1973.*

This sanction was used very sparingly and only in desperate cases, for reasons which may best be described as political. Situations did arise, where a landowner would insist on going ahead with a building, often with the comment that "if the building is destroyed then I will accept the loss". This could not be countenanced as the property could subsequently be sold and the later purchaser would not know of the risk involved.

The Special Building Regulations were promulgated as Statutory Rules 1974, No 291, Building Amendment Regulations (No5) 1974. These controlled building in "B" landslip areas.

Broadly the regulations limited the type of building, the floor area, specified drainage practice, limited excavations, controlled filling and compaction, and demanded certificates from practising engineers or engineering geologists as to the soundness of the development.

THE ADMINISTRATION OF THE SYSTEM

The production of the Risk Maps and the provisions of the *Local Government Act 1961* as amended caused some disquiet amongst authorities, in the newspapers and amongst the public. It then became the task of the Survey team to face the music and be subjected to questioning by councils and members of the public, who often described themselves as "concerned citizens". This was a salutary experience for the geologists, but had two advantages. It was a strict discipline on the geologists involved, and it enabled the geologists to show by their intimate knowledge that they had closely examined the landslide event. It would often disarm criticism if the geologist could show that he had seen a distinctive tree at the property, or had encountered a distinctive dog.

A visit to the site was often arranged when the geologist could demonstrate the geomorphic features of the slide, and relate them to the damage to house or road, and could possibly comment on the faulty drainage. The wide experience afforded by the obligatory "tour" on taking up the work was invaluable in these encounters.

Meetings of this kind were remarkable for their cordiality, and the restraint shown by landowners who might be suffering considerable loss. This can only be explained by the knowledge and professionalism shown by the geologists involved.

EXTRANEOUS PUBLICATIONS

Extraneous publications which arose from the Systematic Survey include 4th AGC (1980) ANZSLIDE87 (1987), Knights & Matthews (1976), Sloane (1985), and Stevenson (1975b). The contributions to ANZSLIDE87 form a useful summary of the work at this date.

AFTERTHOUGHTS

Behind the everyday work done by the landslide team there was always a group of questions that could not be confronted, by reason of immediate demands and lack of resource. These questions involved the geological history and lithologic variation of the Tertiary sediments, of the history of the slopes in Tasmania, the effect of weathering on the slide materials, and the age and origins of the presumed causative uplift. It was apparent that there were generations of landslides, the younger often parasitic on the older, together with the implication that only residual strength is retained in the once-moved material.

These matters remain to be examined so that a fuller picture of the landslide phenomenon will appear, affording greater safety to building construction.

The existence of the advisory landslide risk maps, and the independent advice provided by the Geological Survey, produced a climate of careful building development. In practice this does not appear to have been maintained to the present day.

From the very nature of the Systematic Survey, the losses from landsliding that were prevented cannot be determined. It can only be hoped that as the housing stock ages, the replacement buildings will be built in places which will not endanger them, and by methods that will improve their survival.

ACKNOWLEDGEMENTS

I wish to acknowledge the contributions in various fields, beginning with the erstwhile Minister for Mines, the Hon. Eric Reece who grasped the nettle, and changed the *ad hoc* approach to landslides into a systematic survey. I would of course wish to acknowledge the work of the team which at various times was comprised of Richard Donaldson, Sture Elmer, Ian Jennings, who was also Chief Geologist, Carolyn Knights, David Leaman, Lloyd Matthews, Alan Moon, Bert Moore, John Sloane, Andrew Telfer and Barry Weldon, more than ably assisted by technicians Barry Cox and Richie Woolley and surveyor Geoff Benn. I am indebted to Colin Mazengarb and Michael Stevenson, of Mineral Resources Tasmania, for invaluable help and discussions, and to Carol Bacon for encouragement. This paper and illustrations are published with the permission of the Director of Mines. I thank June Pongratz for her drafting.

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TERRESTRIAL MAMMALS OF A SHEEP-GRAZING PROPERTY ON BRUNY ISLAND, TASMANIA

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(with two text-figures, three plates and seven tables)

Driessen, M.M., Carlyon, K., Gales, R., Mooney, N., Pauza, M., Thurstans, S., Visoiu, M. & Wise, P. 2011 (9:xii): Terrestrial mammals of a sheep-grazing property on Bruny Island, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 145: 51–64. ISSN 0080-4703. Department of Primary Industries, Parks, Water and Environment, PO Box 44, Hobart, Tasmania 7001, Australia (MMD*, KC, RG, NM, MP, ST, MV, PW) *Author for correspondence. Email: Michael.Driessen@dpipwe.tas.gov.au.

Land-based mammals were surveyed in a mosaic of dry sclerophyll forests and pasture on a sheep-grazing property on Bruny Island, Tasmania, using a range of methods in August 2010. This is the first mammal survey of a sheep-grazing property in Tasmania and the first large-scale survey of mammals on Bruny Island. Ten species were recorded comprising seven native and three introduced species. The Little Forest Bat, *Vespadelus vulturnus*, and the Black Rat, *Rattus rattus*, were recorded for the first time on Bruny Island, although both are probably long-term residents. No mammal species listed as rare or threatened under Tasmanian or Australian legislation were found on the property. Large numbers of Eastern Quolls, *Dasyurus viverrinus*, Brushtail Possums, *Trichosurus vulpecula*, Tasmanian Pademelons, *Thylogale billardierii*, and Bennetts Wallabies, *Macropus rufogriseus*, were recorded in a range of dry sclerophyll forests and in pasture. Long-nosed Potoroos, *Potorous tridactylus*, were recorded widely on the property in native vegetation with relatively thick ground cover. Eastern Quoll capture rates were highest in pasture areas and in *Eucalyptus ovata* forest. Brushtail Possums, Long-nosed Potoroos, Tasmanian Pademelons and Bennetts Wallabies were virtually unrecorded from *E. tenuiramis* forest and woodlands. Given the level of survey effort and their potential to occur on the property it was remarkable that no Tasmanian Bettong, *Bettongia gaimardi*, Eastern Barred Bandicoot, *Perameles gunnii*, Southern Brown Bandicoot, *Isoodon obesulus*, or introduced House Mouse, *Mus musculus*, were recorded. We found that camera trapping was more cost-efficient than cage trapping for detecting the presence of mammals on "Murrayfield". Recommendations for ongoing management and monitoring of mammals are provided.

Key Words: mammals, islands, Eastern Quoll, *Dasyurus viverrinus*, management, fire, Bruny Island, Tasmania, sheep farm, camera trapping.

INTRODUCTION

"Murrayfield" is a 4097-ha property on the northern part of Bruny Island, Tasmania, owned by the Indigenous Land Corporation and managed in partnership with the Weetapoonah Aboriginal Corporation. One of the aims for management of the property is to balance the demands of running an established sheep and fine merino wool business with protecting cultural and environmental values (ILC 2009). A native vegetation management plan has been prepared for the property (Sherriff & Magnus 2005). A bird survey (Lloyd 2009) and a preliminary investigation of the geology, geomorphology and landscape evolution of the property have also been completed (Pemberton 2004). At the request of the Weetapoonah Aboriginal Corporation, we undertook a terrestrial mammal survey of the Murrayfield Station. There has been no previous large-scale survey aimed at assessing a range of mammal species on Bruny Island. The only previous study was by Hird (2000) who surveyed Dennes Hill using cage traps and recorded eight species (see below). Furthermore, there has been no previous mammal survey of grazing properties in Tasmania. Previous surveys, targeting a broad range of mammalian taxa, have been in native vegetation communities and mostly in wet forests and heathlands of western Tasmania (Green 1977, 1979, Hocking & Guiler 1983, Green 1984, Taylor *et al.* 1985, Slater 1992, Driessen *et al.* 1995, 2002, Driessen & Jarman 2010). The aims of this survey were: (1) to establish baseline data on mammal populations and to provide recommendations for their ongoing management; and (2) to compare mammal populations between the main vegetation communities on the property.

Existing mammal records for Bruny Island

Before undertaking the survey, we summarised existing information on terrestrial mammals for Bruny Island, obtaining records from published literature and from records held on the Natural Values Atlas—a database of species location records managed by the Tasmanian Department of Primary Industries, Parks, Water and Environment (www.naturalvaluesatlas.tas.gov.au). Records are contributed to this database from a variety of sources including expert and public observations, permit reports and publications.

Woinarski (1985) reported Gould's Wattled Bat, *Chalinolobus gouldii* (Gray, 1841) roosting in a stump on northern Bruny Island. Ziegeler (1971) observed a Short-beaked Echidna, *Tachyglossus aculeatus* (Shaw, 1792) at Adventure Bay. Hird (2000) surveyed Dennes Hill Reserve in 1996 and recorded the presence of eight mammal species (table 1). He also reported an unpublished observation of a Lesser Long-eared Bat, *Nyctophilus geoffroyi* Leach, 1821. In a review of the distributions of mammals in Tasmania, including offshore islands, Rounsevell *et al.* (1991) mapped the distribution of native terrestrial mammals using records from the TASPAWS Biological Records Scheme (which morphed into the Natural Values Atlas). They documented 13 mammal species on Bruny Island (table 1). Cochran (2003) mentioned the occurrence of Little Pygmy Possums, *Cercartetus lepidus* (Thomas, 1888) in her compilation of information on threatened species on Bruny Island, and Hird (2009) recorded both Little Pygmy Possums and Eastern Pygmy Possums, *Cercartetus nanus* (Geoffroy & Desmarest, 1817) in artificial nest boxes adjacent to the airstrip on northern Bruny Island. Driessen *et al.* (2011)

TABLE 1
Existing records of native and introduced terrestrial mammals on Bruny Island

Species		Northern Bruny	Southern Bruny	Source
Native Mammals				
Platypus	*Ornithorhynchus anatinus*	-	+	1,2
Short-beaked Echidna	*Tachyglossus aculeatus*	+	+	1,2
Spotted-tailed Quoll	*Dasyurus maculatus*	-	-	
Eastern Quoll	*Dasyurus viverrinus*	+	+	1,2,3
Tasmanian Devil	*Sarcophilus harrisii*	-	-	
Swamp Antechinus	*Antechinus minimus*	-	+	1,2
Dusky Antechinus	*Antechinus swainsonii*	-	+	1,2
White-footed Dunnart	*Sminthopsis leucopus*	-	+	1,2
Southern Brown Bandicoot	*Isoodon obesulus*	-	+	1
Eastern Barred Bandicoot	*Perameles gunnii*	-	+	2
Smooth-nosed Wombat	*Vombatus ursinus*	-	-	
Ringtail Possum	*Pseudocheirus peregrinus*	+	-	3
Sugar Glider	*Petaurus breviceps*	-	-	
Brushtail Possum	*Trichosurus vulpecula*	+	+	1,2,3
Little Pygmy Possum	*Cercatetus lepidus*	+	+	1,4,5
Eastern Pygmy Possum	*Cercatetus nanus*	+	+	5
Long-nosed Potoroo	*Potorous tridactylus*	+	+	1,2,3
Tasmanian Bettong	*Bettongia gaimardi*	+	+	1,2
Tasmanian Pademelon	*Thylogale billardierii*	+	+	1,2,3
Bennetts Wallaby	*Macropus rufogriseus*	+	+	2,3
Forester Kangaroo	*Macropus giganteus*	-	-	
Water Rat	*Hydromys chrysogaster*	+	-	3
Long-tailed Mouse	*Pseudomys higginsi*	-	+	1
New Holland Mouse	*Pseudomys novaehollandiae*	-	-	
Broad-toothed Mouse	*Mastacomys fuscus*	-	-	
Swamp Rat	*Rattus lutreolus*	-	+	2
Goulds Wattled Bat	*Chalinolobus gouldii*	+	-	7
Chocolate Wattled Bat	*Chalinolobus morio*	-	-	
Large Forest Bat	*Vespadelus darlingtoni*	-	-	
Southern Forest Bat	*Vespadelus regulus*	-	-	
Little Forest Bat	*Vespadelus vulturnus*	-	-	
Tasmanian Pipistrelle	*Falsistrellus tasmaniensis*	-	-	
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	-	+	3
Tasmanian Long-eared Bat	*Nyctophilus sherrini*	-	-	
Total		12	18	
Introduced Mammals				
Goat	*Capra hircus*	-	+	2
Cat	*Felis catus*	-	+	2
House Mouse	*Mus musculus*	-	+	2
Rabbit	*Oryctolagus cuniculus*	+	-	2
Fox	*Vulpes vulpes*	+	-	6
Total		2	3	

1 = Rounsevell *et al.* (1991), 2 = Natural Values Atlas, 3 = Hird (2002), 4 = Cochran (2003),
5 = (Hird 2009), 6 = DPIPWE (2011), 7 = Woinarski (1985) '–' = not recorded

reviewed the status and conservation of bats in Tasmania but provided no additional records for the island.

Twenty-one native terrestrial mammal species (59% of State total) have been recorded from Bruny Island (table 1). Of the remaining 13 Tasmanian species that have not been recorded on the island, seven are unlikely to be found there. They are the Broad-toothed Mouse, *Mastacomys fuscus* Thomas, 1882, New Holland Mouse, *Pseudomys novaehollandiae* (Waterhouse, 1843) (unsuitable habitat and both species not known from southeast Tasmania), Tasmanian Devil, *Sarcophilus harrisii* (Boitard, 1841), Spotted-tailed Quoll, *Dasyurus maculatus* (Kerr, 1792), Smooth-nosed Wombat, *Vombatus ursinus* (Shaw, 1800), Eastern Grey Kangaroo, *Macropus giganteus* Shaw, 1790 (conspicuous species that have not been recorded on the island, at least in recent times) and the Sugar Glider, *Petaurus breviceps* Waterhouse, 1839.

Although the Sugar Glider is known from the adjacent Tasmanian mainland, it is unlikely to occur on the island if, as has been suggested by Green (1973), it was introduced to Tasmania in colonial times. There are observations of possible Tasmanian Devils occurring on southern Bruny Island contained in meeting notes of the Royal Society of Tasmania in 1871 (K. Medlock, Tasmanian Museum and Art Gallery and D. Pemberton, Department of Primary Industries, Parks, Water and Environment, unpublished data); however, there is no other evidence of devils occurring on the island. The Natural Values Atlas contains a 1996 record of a Spotted-tailed Quoll near Apollo Bay on northern Bruny Island and Hird (2000 p.11) mentioned that a resident of northern Bruny Island "had trapped a spotted-tailed quoll near Dennes Hill in a possum cage". It is not clear if these two records are of the same incident. Menna Jones (pers. comm., University of Tasmania), who received the Natural Values Atlas record by phone from a member of the public, could not confirm the identification. Given the lack of any other evidence for Spotted-tailed Quolls on the island, we assume that this species does not occur there. The remaining six species (all bats) have a high probability of occurring on the island due to suitable habitat there and known populations on the adjacent Tasmanian mainland (Driessen *et al.* 2011).

The northern and southern parts of Bruny Island are separated by a narrow isthmus, called The Neck, which is approximately 2 km long and 100 m wide at its narrowest part. A greater number of terrestrial mammal species has been recorded on southern Bruny Island (18 species) than on northern Bruny Island (12 species) (table 1). Hird (2000) questioned whether the Eastern Barred Bandicoot, *Perameles gunnii* Gray, 1838 has been recorded from northern Bruny Island as reported by Rounsevell *et al.* (1991) because the scale of mapping used in the latter paper was not sufficient to delineate between Bruny Island and the Tasmanian mainland. In support of Hird (2000) we found no records of the Eastern Barred Bandicoot for northern Bruny Island on the Natural Values Atlas.

The difference in number of mammal species between northern and southern Bruny Island is most likely because of vegetation differences. Southern Bruny Island contains wet forests and coastal heathlands which are virtually absent from northern Bruny Island, which would explain the occurrence on southern Bruny Island of the Long-tailed Mouse, *Pseudomys higginsi* (Trouessart, 1897), Swamp Rat, *Rattus lutreolus* (Gray, 1841), Dusky Antechinus, *Antechinus swainsonii* (Waterhouse, 1840), and Swamp Antechinus, *Antechinus minimus* (Geoffroy, 1803). The Neck, which is dominated by road, sand, mud and sparse coastal vegetation, may act (or have acted since the last sea level rise) as a barrier to mammal dispersal between the two parts of the island.

Seven species (Tasmanian Bettong, Long-tailed Mouse, Swamp Rat, Swamp Antechinus, Dusky Antechinus, White-footed Dunnart *Sminthopsis leucopus* (Grey, 1842), and Platypus, *Ornithorhynchus anatinus* (Shaw, 1799), were last recorded on the island in the 1970s and 1980s.

In addition to native terrestrial mammals, five species of introduced mammals have been recorded living wild on Bruny Island (table 1). One Fox scat, *Vulpes vulpes* Linnaeus, 1758, confirmed by DNA testing, was found on northern Bruny Island in May 2010 (DPIPWE 2011). Follow-up surveys using scat-detector dogs were undertaken but the scats collected tested negative for Fox (R. Gaffney, Fox Eradication Branch, pers. comm.). Other introduced mammal species expected to occur on the island include Black Rats, *Rattus rattus* (Linnaeus, 1758), and Brown Rats, *Rattus norvegicus* (Berkenhout, 1769).

Bruny Island is the fourth largest offshore island in Tasmania (36 200 ha) and has the highest number of native terrestrial mammal species of any Tasmanian island (19 species excluding bats, which have been poorly surveyed). The three larger islands—Flinders Island (133 300 ha, 13 species), King Island (110 160 ha, 12 species) and Cape Barren Island (47 840 ha, six species)—all contain fewer species (based on number of species at time of European settlement reported by Hope (1972) and Rounsevell *et al.* (1991)). Bruny Island is the only island in Tasmania known to have naturally occurring populations of Eastern Quolls, Eastern Barred Bandicoots, Tasmanian Bettongs, Long-tailed Mice, Dusky Antechinus and Little Pygmy Possums. The greater number of species on Bruny Island is likely to be a result of a range of wet and dry habitats present on the island and perhaps close proximity (closest point = 2 km) to the Tasmanian mainland with a relatively shallow intervening channel (shallowest depth = 11 m). In comparison, Cape Barren Island, which is the closest of the three larger islands, is over 30 km from the Tasmanian mainland with the shallowest connecting depth approximately 24 m. Hence, Bruny Island would have been connected to the Tasmanian mainland more frequently and for longer periods than the other three large islands, increasing the likelihood of mammal colonisation from the Tasmanian mainland.

METHODS

Site description

A comprehensive description of the property is given in the Murrayfield Native Vegetation Management Plan (Sherriff & Magnus 2005) and is summarised here. "Murrayfield" is 4097 ha in size and covers about half of Bruny Island north of The Neck (pl. 1). Approximately half of the total area of the property is native vegetation, most of which is in good condition, and the remainder is pasture. The native vegetation is predominantly dry sclerophyll vegetation types with several patches of mixed wet sclerophyll vegetation in gullies. Images of two of the main native vegetation types on the property are shown in pls 2 and 3. Approximately 12 000 sheep are run on the property. Adjoining properties are mostly private farming land or rural residential. Bruny Island Neck Game Reserve borders the southern boundary of the

PLATE 1
Location of "Murrayfield" and trap stations.

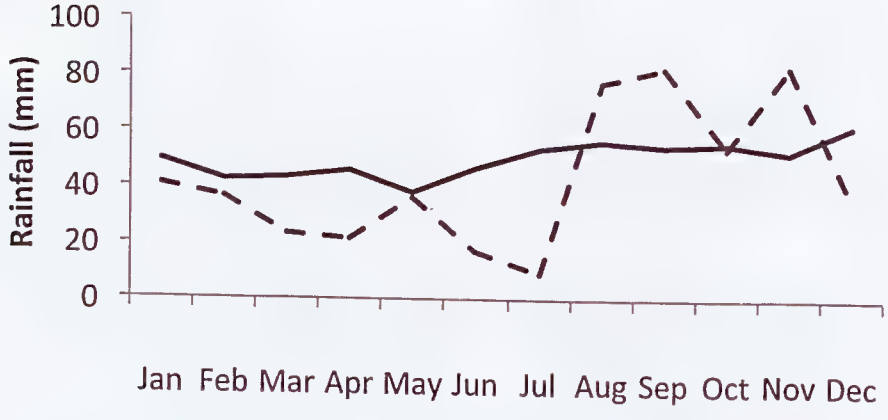

FIG. 1 — Mean monthly rainfall (solid line, 1984–2010) and monthly rainfall for 2010 (dashed line). Source: Bureau of Meteorology, Bull Bay Weather Station.

property. Wallabies and possums on the property are subject to regular culling under licence for crop protection purposes.

Mean annual rainfall for northern Bruny Island is 673 mm (based on Bureau of Meteorology records from Bull Bay for the period 1984–2010). Highest mean monthly rainfalls occur from July to December with December receiving the highest total on average (fig. 1). Mean monthly maximum temperatures range from 21.2 °C in January and February to 12.5 °C in July. Mean monthly minimum temperatures range from 12.6 °C in February to 5.8 °C in July. For the eight months prior to our survey in August 2010 (December 2009–July 2010) rainfall was 60% below the long-term average for that same period of months (fig. 1). Mean minimum and monthly temperatures during this eight month period were higher than the long-term mean with some mean monthly values up to a degree warmer.

Mammal survey techniques

The survey was conducted during August 2010 using a range of techniques. To gain a full picture of the abundance and distribution of mammals in relation to "Murrayfield"'s vegetation types and land uses, we aimed to survey mammals in all major vegetation types on the property and distributed our sampling effort to obtain a good spatial coverage of the property. Sites were biased towards locations with vehicle access.

Live Trap and Release

Mammal trapping occurred over three nights (23–26 August), using cage traps (25 x 25 x 56 cm, Mascot Wireworks) and aluminium box traps (11 x 11 x 33 cm, Elliott Scientific). At most locations one cage and one box trap were set every 100 m along a transect, which typically followed a track, with traps placed 10–30 m into the trackside vegetation. The exceptions to this pattern occurred at Roberts Hill, Lodge Hill and Kirkby Creek. At Roberts Hill a box trap alternated with a box/cage trap pair every 50 m for 1.4 km and then six box traps were set every 50 m in at the end of this line. At Lodge Hill, a box trap alternated with a box/cage trap pair every 50 m along the track to the top of the hill. A further six cage/box trap pair was set every 50 m around the side of Lodge Hill. At Kirkby Creek, six cage/box trap pairs were set every 50 m along the gully. In addition, at Church Hill, an extra four box traps were set along the dry creekline for three nights. Trap locations are shown in pl. 1 and the numbers of traps set at each location is given in table 2. Cage traps were baited with peanut butter sandwiches and were covered with plastic or hessian bags to protect trapped animals from the elements. Box traps were baited with peanut butter and rolled oats balls and covered with plastic bags. Dacron was placed in all traps for insulation. A harp trap was set to capture bats on the vehicle tracks at the Saltmarsh location (3 nights) and the Cockatoo Gully location (2 nights) and checked each evening and morning. Only two harp traps were available and we chose locations that we assumed would have a good chance of catching bats—a track with dense vegetation either side and with some over-hanging branches. Most animals captured had the following recorded: species, sex, head length, hind foot length and reproductive status. The forearms of bats were measured to aid species identification. A small hair clip was taken to mark each animal caught except bats, Short-beaked Echidnas and Brushtail Possums, *Trichosurus vulpecula* (Kerr, 1792). Echidnas and Brushtail Possums were not handled. Each trap location was assigned to a TASVEG vegetation group based on TASVEG mapping and ground-truthing (table 2).

Camera Traps

Ten remote cameras (Digital Eye, Pix Controller Inc.) were set up on 20 August 2010 and retrieved 17 days later on 6 September 2010. The traps were deployed in areas with road access and with the aim of getting broad spatial and vegetation coverage. Two cameras were placed on Church Hill to survey the dry forest on the ridge and the wet forest in the gully. The cameras were placed on a small tree trunk 75 cm above the ground. The attractant—comprising peanut butter, rolled oats and tuna oil—was placed in a PVC capsule 1.5 m from the camera. The capsule, which had a conical lid with slits, was partially buried in the ground and anchored with a tent peg. The cameras were set for continuous recording with a 30-second delay between photos. The passive infra-red sensor was triggered by movement or heat. Locations of camera traps are shown in pl. 1. We provide information on the number of images captured for each mammal species for each camera. This information should be used with caution as we do know how many individual animals were recorded and hence may not be indicative of relative abundance.

Spotlighting

Spotlighting was undertaken from a vehicle each night (3 nights) along the main tracks on the station: Variety Bay (start: 531600E, 5217300N; finish: 534400E, 5216000N), grass tree track (529300E, 5220300N; 528938E, 5223000N), Yellow Bluff (530500E, 5223500N; 531400E, 5223900N), Lodge Hill (527800E, 5222000N; 528100E, 5223000N), Trumpeter Bay Road (531700E 5220800N; 532900E, 5217200N) and shortcut paddock (531300E, 5220900N, 530700E; 5220000N). Spotlighting was repeated on Trumpeter Bay Road and grass tree track to gauge nightly variation in the spotlight counts. The passenger and driver each used a 100-W halogen spotlight to cover their respective sides of the track, taking care not to double count animals crossing the track in front of the vehicle. We compared our spotlight counts of mammal species with annual averages from the statewide spotlight surveys for 1985–1990 (Driessen & Hocking 1992). The statewide spotlight surveys cover a wide range of vegetation types and no comparisons of mammal counts between vegetation types has been published. Thus the average spotlight counts presented by Driessen & Hocking (1992) include transects that traverse vegetation types that may not support some mammal species.

Mammal sign

Any signs of mammals such as scats, skulls, diggings and nests were noted opportunistically.

RESULTS AND DISCUSSION

Ten terrestrial mammal species were recorded on "Murrayfield" of which seven are native to Tasmania and three are introduced species (excluding domesticated species) (table 3). The Little Forest Bat, *Vespadelus vulturnus* (Thomas, 1914), and the Back Rat have not been recorded previously from the island although no doubt local residents would be aware of Black Rats. The Eastern Quoll and the Tasmanian Pademelon, *Thylogale billardierii* (Desmarest, 1822) are now restricted to Tasmania; Australian mainland populations became extinct in the twentieth century (Johnson & Rose 2008,

TABLE 2
Number of trap nights by vegetation type

Location	Trap Type	DAC	DGL	DOB	DOV	DPU	DTO	FAG	WGL	Total
Church Hill	C			6			24			30
	B			18			24			42
Cockatoo Gully	C				8	6				14
	B				8	4				12
Grass Tree	C	15						15		30
	B	15						15		30
Kirkby Creek	C		18							18
	B		18							18
Lodge Hill	C					30				30
	B					42				42
Murrayfield	C			5						5
Roberts Hill	C					45				45
	B					99			6	105
Saltmarsh	C	30								30
	B	30								30
Shearing Quarters	C							5		5
Variety Bay	C						30			30
	B						30			30
Yellow Bluff	C					20				20
	B					20				20
Total	C	45	18	11	8	101	54	20	0	257
	B	45	18	18	8	165	54	15	6	329

C = cage trap and B = Box trap. DAC = *Eucalyptus amygdalina* coastal forest and woodland, DGL = *E. globulus* dry forest and woodland, DOB = *E. obilqua* dry forest, DOV = *E. ovata* forest and woodland, DPU = *E. pulchella* forest and woodland, DTO = *E. tenuiramis* forest and woodland on sediments, FAG = agricultural land, WGL = *E. globulus* wet forest.

TABLE 3
List of mammal species recorded on "Murrayfield"

Species		Status	Method of Detection
Short-beaked Echidna	*Tachyglossus aculeatus*	N	L, C, O, D
Eastern Quoll	*Dasyurus viverrinus*	Ne	L, C, Osp, T, Sc
Brushtail Possum	*Trichosurus vulpecula*	N	L, C, Osp, Sc
Long-nosed Potoroo	*Potorous tridactylus*	N	L, C, Osp, T, D
Tasmanian Pademelon	*Thylogale billardierii*	Ne	C, Osp, Sc
Bennetts Wallaby	*Macropus rufogriseus*	N	C, Osp, Sc
Little Forest Bat	*Vespadelus vulturnus*	N	L
Domestic Cat	*Felis catus*	I	L
Black Rat	*Rattus rattus*	I	L, C
European Rabbit	*Oryctolagus cuniculus*	I	Osp, Sc

N=native species, e = endemic species, I = introduced species, C=camera trap, D=digging, L=live trap and release, O=observed, Osp=observed by spotlighting, Sc=scat, T=tracks.

Jones 2008). Currently three species of extant, terrestrial mammal are listed on the Tasmanian *Threatened Species Protection Act 1995* (New Holland Mouse, Tasmanian Devil and Spotted-tailed Quoll) and these are unlikely to occur on the island (see above). The Eastern Barred Bandicoot is listed on the Australian *Environment Protection and Biodiversity Conservation Act 1999*. It has been previously recorded on Bruny Island and has the potential to occur on the property but was not recorded during our survey (see below).

Monotremes

Short-beaked Echidna

Four Short-beaked Echidnas were recorded in four different vegetation types: *Eucalyptus pulchella* Desf. forest, *E. tenuiramis* Miq. forest, *E. amygdalina* Labill. coastal forest and pasture (tables 4–7). Diggings made by echidnas were observed widely throughout the property. Similarly, Hird (2000) found that echidna diggings were common on Dennes Hill and around the Denne's farm.

Marsupials

Eastern Quoll

Only one carnivorous marsupial was recorded on "Murrayfield", the Eastern Quoll. This species was commonly and widely recorded on the property using cage traps, camera traps and spotlighting (tables 4–7). The capture rate was 26 individuals caught per 100 cage trap nights which is considerably higher than rates reported in rainforest, wet forest, heathland and alpine vegetation elsewhere in Tasmania where less than one Eastern Quoll was caught per 100 cage trap nights (Hocking & Guiler 1983, Taylor *et al.* 1985, Driessen *et al.* 1995). Our capture rates were also higher than those of Hird (2000) who caught one Eastern Quoll in 75 trap nights on Dennes Hill in 1996 in habitat similar to that found on "Murrayfield", suggesting that quoll numbers may have increased since that time. Our capture rates were similar to those found in *E. tenuiramis* forest and woodland in southeast Tasmania two years after a cool fire (Driessen *et al.* 1991). However, the captures rates recorded by Driessen *et al.* (1991) declined significantly four years later and they suggested that this may be associated with decreases in invertebrate prey. Eastern Quolls were captured in all major vegetation types surveyed but there was a significant difference in capture rates between vegetation types ($\chi^2 = 14.625$, df = 6, $p < 0.026$) with a higher capture rate in *E.ovata* Labill. forest and in pasture areas than in other vegetation types (fig. 2). Eastern Quolls reach their highest densities where pasture is adjacent to eucalypt forest (Jones & Rose 2001) probably because of the abundant invertebrate food resource in pastures adjacent to native vegetation cover. The high captures of Eastern Quolls in *E.ovata* Labill. forest should be regarded with caution as our survey effort in this vegetation type was limited (8 trap nights). However, *E.ovata* forests are associated with drainage flats and fertile soils (Harris & Kitchener 2005) and may provide good invertebrate foraging areas for quolls.

Eastern Quolls were recorded on most spotlight transects at an overall rate of 10 quolls per 10 km. This rate is much greater than the maximum average rate (0.5 quolls per 10 km) recorded on 130 10-km transects during the annual statewide spotlight survey program between 1985 and 1990 (Driessen & Hocking 1992), and supports the view that quoll numbers were high during the survey of "Murrayfield". We do not know why Eastern Quoll abundance was high during our survey.

A total of 68 different Eastern Quolls were caught and measured during the survey which allowed further investigation of the characteristics of the population. One female with pouch young was caught in a box trap and all other animals were caught in cage traps. The sex ratio of 38 males to 30 females did not differ significantly from parity ($\chi^2=0.94$, df=1, $p>0.5$). The mean body weights (±s.e.) of male and female quolls were 1061 ± 33.8 g (range: 700–1620, n=38) and 783 ± 24.5 g (range: 500–1120 g, n=30) respectively. These average body weights are comparable with the averages reported by Green (1967) for northeastern Tasmanian quolls but lighter (200 g for males and 100 g for females) than the average body weights reported for the species (Jones 2008). The survey timing (August) probably contributed to our light body weights. In winter Eastern Quoll body weights can be 16–31% lighter than in summer (Jones & Rose 2001). One male Eastern Quoll appeared to be in very poor condition; it had a high parasite load (ticks and fleas) and sparse fur and was skinny. It also had a thickened, raised, bare patch of skin on its abdomen. All but three females showed signs of having young or recently having had young. Half of the females (15/30) had pouch young, ranging in size and hairiness from about 10 mm and unfurred to about 45 mm and lightly furred and pigmented such that spots could be discerned. The number of pouch young ranged from 1–6 (average 4.4). The coat colour (light or dark) was recorded for 63 of the 68 quolls trapped. Sixty-two percent (39 animals) had light colour coats and this percentage was consistent regardless of sex (63% for females and 61% for males). This proportion of light colour coats is less than the proportion (75%) reported by Jones & Rose (2001).

Brushtail Possum

Brushtail Possums were recorded throughout "Murrayfield" using cage traps, cameras and spotlighting (tables 4–7). Large numbers of Brushtail Possums were seen while spotlighting on each of two nights in paddocks along Trumpeter Bay Road (table 7) and were considerably higher than those reported from annual statewide spotlight surveys (<8 per 10 km transect, Driessen & Hocking 1992). These areas of the property have better quality pastures (B. Michael, Murrayfield Station, pers. comm.). Spotlight counts of possums were consistent between nights on the Trumpeter Bay Road transect but not for the grass tree track transect (table 7). It is not known why there was a difference on the grass tree track. Different observers may have contributed to this but counts of other animals were similar between the two nights. Relatively few Brushtail Possums were caught in cage traps and only at five of the ten locations (table 5). Hird (2000) did not trap any Brushtail Possums at Dennes Hill but noted that many were seen on roads. Our capture rates were similar to those found in *E. tenuiramis* forest and woodland in southeast Tasmania two years after a cool fire (Driessen *et al.* 1991). However, the captures rates recorded by Driessen *et al.* (1991) increased significantly four years later and they attributed this to vegetation changes following fire. Our Brushtail Possum capture rates were also similar to those reported from coastal heathlands and scrub of the Waterhouse Area (Driessen *et al.* 1995). Camera traps appeared to be more efficient than cage trapping in recording Brushtail Possums with detection at seven of the ten locations (table 6). Brushtail Possums were recorded in most vegetation types but were absent from *E.*

TABLE 4
Number of mammals caught in cage traps at each location

Location	Trap Nights	ECH	EQ	BP	LNP	Cat	BR
Church Hill	30	0	9 (2)	0	0	0	0
Cockatoo Gully	14	1	5 (1)	0	0	0	0
Grass Tree/Pasture	30	0	12 (0)	1	0	0	0
Kirkby Creek	18	0	6 (1)	2	0	0	0
Lodge Hill	30	0	7 (3)	4	4 (0)	0	1
Roberts Hill	45	0	14 (3)	0	5 (1)	0	0
Saltmarsh	30	0	9 (0)	1	1 (0)	1	0
Shearing Quarters	5	0	3 (0)	2	0	0	0
Variety Bay	30	0	14 (2)	0	0	0	0
Yellow Bluff	20	0	1 (0)	0	0	0	0
Murrayfield	5	0	0 (0)	0	2 (0)	0	0
Total	257	1	80 (12)	10	12 (1)	1	1

Values = captures + recaptures. Numbers in parentheses = recaptures. ECH = Echidna, *Tachyglossus aculeatus*, EQ = eastern Quoll, *Dasyurus viverrinus*, BP = Brushtail Possum, *Trichosurus vulpecula*, LNP = Long-nosed Potoroo, *Potorous tridactylus*, Cat, *Felis catus*, BR = Black Rat, *Rattus rattus*

TABLE 5
Number of mammals caught in cage traps by vegetation type

Vegetation Type	Trap Nights	ECH	EQ	BP	LNP	Cat	BR
DAC	45	0	14 (0)	2	1	1	0
DGL	18	0	6 (1)	2	0	0	0
DOB	11	0	4 (1)	0	2	0	0
DOV	8	0	5 (1)	0	0	0	0
DPU	101	1	22 (6)	4	9 (1)	0	1
DTO	54	0	19 (3)	0	0	0	0
FAG	20	0	10 (0)	2	0	0	0
Total	257	1	80 (12)	10	12 (1)	1	1

Values = captures + recaptures. Numbers in parentheses = recaptures. ECH = Short-beaked Echidna, *Tachyglossus aculeatus*, EQ = eastern Quoll, *Dasyurus viverrinus*, BP = Brushtail Possum, *Trichosurus vulpecula*, LNP = Long-nosed Potoroo, *Potorous tridactylus*, Cat, *Felis catus*, BR = Black Rat, *Rattus rattus*. Vegetation codes: DAC = *Eucalyptus amygdalina* coastal forest and woodland, DGL = *E. globulus* dry forest and woodland, DOB = *E. obilqua* dry forest, DPU = *E. pulchella* forest and woodland, DTO = *E. tenuiramis* forest and woodland on sediments, WGL = *E. globulus* wet forest, FAG = agricultural land (pasture). ECH = Short-beaked Echidna, *Tachyglossus aculeatus*, EQ = Eastern Quoll, *Dasyurus viverrinus*, BP = Brushtail Possum, *Trichosurus vulpecula*, LNP = Long-nosed Potoroo, *Potorous tridactylus*, TP = Tasmanian Pademelon, *Thylogale billardierii*, BW = Bennetts Wallaby, *Macropus rufogriseus*, BR = Black Rat, *Rattus rattus*.

TABLE 6
Mammal species detected (x) by each of 10 camera traps

Location	Veg. Type	ECH	EQ	BP	LNP	TP	BW	BR
Church Hill	DOB		x (53)	x (24)		x (1)	x (2)	x (2)
Church Hill	DTO	x (2)	x (12)	x (42)	x (1)		x (7)	
Saltmarsh	DAC		x (12)	x (10)		x (18)		
Grass Tree	DAC	x (4)	x (29)	x (68)	x (107)	x (9)	x (2)	
South of Church Hill	DTO	x (19)			x (2)		x (10)	
Roberts Hill	DPU		x (22)		x (8)			
Lodge Hill	DPU		x (18)	x (16)	x (25)		x (12)	x (59)
Roberts Hill	WGL		x (7)	x (7)		x (3)	x (9)	x (4)
Kirkby Creek	DGL/FAG		x (7)					
Yellow Bluff	DPU			x (5)	x (6)			
Total locations		3	8	7	6	4	6	3
Total images		25	160	172	149	31	42	65

Values in parentheses are the number of images taken of that species. Vegetation and species codes as for table 5.

TABLE 7
Number of mammals recorded on spotlight survey transects

Location	Date	Distance (km)	Start time	End time	ECH	EQ	BP	POT	TP	BW	RAB
Variety Bay	23/08/2010	5.0	2113	2151	0	0	0	0	13	21	6
Grass Tree Track	23/08/2010	3.6	2110	2215	0	11	42	0	12	6	0
Yellow Bluff	24/08/2010	1	2020	2035	0	0	3	0	0	0	0
Lodge Hill	24/08/2010	1	2045	2100	0	0	3	0	0	0	0
Grass Tree Track	24/08/2010	3.6	2115	2200	0	7	14	0	19	7	0
Trumpeter Bay Road	24/08/2010	4.7	2013	2103	0	3	89	0	14	11	2
Trumpeter Bay Road	25/08/2010	4.8	2114	2201	0	2	100	1	10	12	2
Shortcut paddock	25/08/2010	1.8	2054	2108	1	2	2	0	0	0	0
Total		25.5			1	25	253	1	68	57	10

Conditions during surveys were; no rain, cloudy, full moon and light or no wind. ECH = Short-beaked Echidna, *Tachyglossus aculeatus*, EQ = Eastern Quoll, *Dasyurus viverrinus*, BP = Brushtail Possum, *Trichosurus vulpecula*, LNP = Long-nosed Potoroo, *Potorous tridactylus*, TP = Tasmanian Pademelon, *Thylogale billardierii*, BW = Bennetts Wallaby, *Macropus rufogriseus*, RAB = Rabbit, *Oryctolagus cuniculus*.

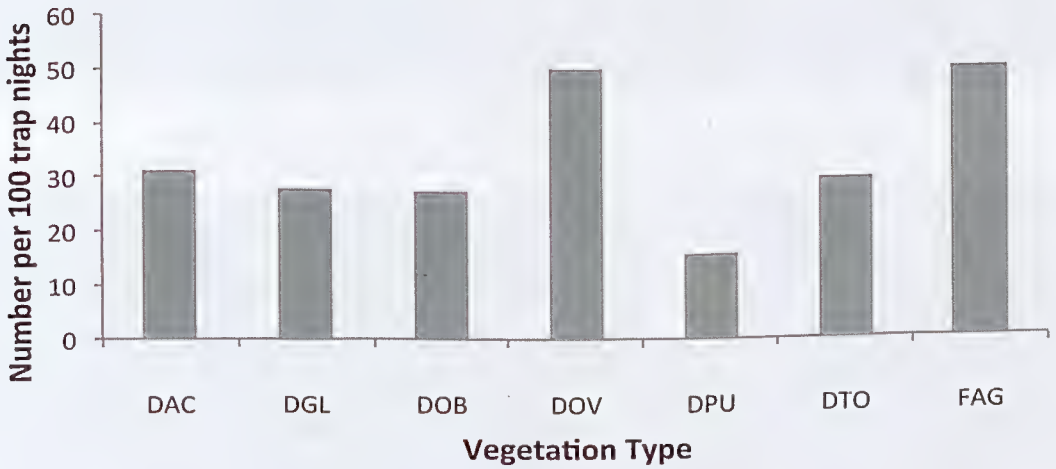

FIG. 2 — Rate of Eastern Quoll captures in cage traps in different vegetation types. Recaptures were not included. DAC = Eucalyptus amygdalina *coastal forest and woodland, DGL* = E. globulus *dry forest and woodland, DOB* = E. obilqua *dry forest, DOV* = E. ovata *forest and woodland, DPU* = E. pulchella *forest and woodland, DTO* = E. tenuiramis *forest and woodland on sediments, FAG = pasture.*

tenuiramis forest and woodland perhaps suggesting that this species rarely uses this vegetation type which occur on nutrient-poor soils with low understorey species diversity (pl. 3) (Harris & Kitchener 2005).

Long-nosed Potoroo

Long-nosed Potoroos, *Potorous tridactylus* (Kerr, 1792) were widely distributed across the property in areas with native vegetation cover (tables 4–7) and that had relatively dense ground cover as shown in plate 2. They were mostly recorded using cage traps and cameras. We trapped 11 potoroos comprising five females and six males. All females carried pouch young that were small (<7 cm crown-rump length) and unfurred. Our traps success (5%) was similar to that recorded in similar vegetation at Dennes Hill (8%, Hird 2000) but considerably less than that recorded in *E. amygdalina* Labill. heathland (26%, Driessen & Jarman 2010). Despite the relatively large trapping effort in *E. tenuiramis* forest and woodland no potoroos were caught in this habitat. Although one image of a potoroo was caught on camera in this habitat, the results suggest that *E. tenuiramis* forest and woodland supports very low numbers of this species. A major habitat requirement for this species is relatively thick ground cover (Johnston 2008). *Eucalyptus tenuiramis* forest and woodland occurs on nutrient-poor soils and often has very sparse ground cover (Harris & Kitchener 2005) as shown in plate 3. Only one potoroo was recorded while spotlighting which is consistent with low levels of detection during annual statewide spotlight surveys (Driessen & Hocking 1992).

PLATE 2
Eucalyptus pulchella *forest at Roberts Hill (Photo: M. Driessen).*

PLATE 3
Eucalyptus tenuiramis *forest near Variety Bay (Photo: R. Gales).*

Tasmanian Pademelon and Bennetts Wallaby

The Tasmanian Pademelon and Bennetts Wallaby were primarily recorded by spotlighting and observing their scats and skulls (of shot animals). They were widely distributed and relatively abundant in pasture areas and were observed fleeing into adjacent vegetation during spotlighting. The number of Tasmanian Pademelons (27) and Bennetts Wallaby (23) seen per ten kilometres is considerably higher than the average rate observed during annual statewide spotlight surveys between 1985 and 1990 (<10 animals per 10 km, Driessen & Hocking 1992) suggesting relatively large numbers of wallabies on the property. The large size of the wallabies precluded them from being caught in our cage traps (although small individuals are rarely caught). Camera traps recorded few images of Tasmanian Pademelons and at few locations. This species was not recorded on cameras in *E. tenuiramis* forest and woodland or *E. pulchella* forest and woodland. Camera traps also recorded few images of Bennetts Wallabies but they were recorded at more locations and in more habitats than the Tasmanian Pademelon. It is possible that the baits used to attract these two species to the cameras may not be effective.

Eutherians

Little Forest Bat

The time of the year and the weather conditions during the survey were not ideal for trapping and recording bats. Nevertheless, four Little Forest Bats—two adult males and two adult females— were caught in the harp trap. All bats were caught at the Saltmarsh location on the first night of survey which was before the cold change in weather occurred. Unfortunately, time constraints meant that the harp trap at Cockatoo Gully was not set until after the first night. We are not aware of any previous bat surveys on Bruny Island. A bat survey during warmer months is likely to increase the number of bats species detected on the property.

Introduced species

Cat

Only one Cat, *Felis catus* Linnaeus, 1758 was recorded during the survey. It was caught in a cage trap at the Saltmarsh location. No cats were recorded on camera or seen while spotlighting. Cats are rarely cage-trapped during mammal surveys in Tasmania despite evidence of their presence either by direct observation or by observation of sign (Hocking & Guiler 1983, Taylor *et al.* 1985, Slater 1992, Driessen *et al.* 1995, Driessen & Jarman 2010). Cats are also rarely observed on the annual statewide spotlight surveys with less than ten cats seen annually on the 130 10-km routes (Driessen & Hocking 1992).

European Rabbit

Remarkably few European Rabbits, *Oryctolagus cuniculus* (Linnaeus, 1758) were observed on "Murrayfield". Ten rabbits were seen while spotlighting (3.9 per 10 km) which is a little higher than the numbers observed annually during statewide spotlight surveys (<3 per 10 km transect, Driessen & Hocking 1992). Because our spotlight surveys were conducted in pasture areas we would have expected higher rabbit counts. The managers of "Murrayfield" reported that rabbit numbers were far greater on southern Bruny Island and speculated that Eastern Quolls may be limiting the growth of the rabbit population on northern Bruny Island.

Black Rat

Few Back Rats were recorded during the survey. Camera traps recorded them at three separate locations: in the gullies near Church Hill and Roberts Hill and in *E. pulchella* woodland on Lodge Hill. One was trapped in a cage trap on Lodge Hill. It is possible that with greater trapping effort around the shearing shed more might have been recorded. Black Rats have been rarely recorded in previous Tasmanian mammal surveys in native vegetation (Hocking & Guiler 1983, Taylor *et al.* 1985, Slater 1992, Hocking & Driessen 2000, Driessen *et al.* 2002) and most have been recorded in coastal vegetation (Slater 1992, Driessen *et al.* 1995).

Species not recorded

Several species of mammal were absent from this survey, and this is surprising given the suitability of the habitat present on "Murrayfield" and the large survey effort. The Southern Brown Bandicoot, *Isoodon obesulus* (Ramsay, 1887), Eastern Barred Bandicoot and Tasmanian Bettong have previously been recorded on Bruny Island (table 1) and all are readily caught in cage traps. The Southern Brown Bandicoot is often recorded where Long-nosed Potoroos occur and in pasture/native bush mosaics (Heinsohn 1966, Mallick *et al.* 1998, Driessen & Jarman 2010). It was both surprising and pleasing that no introduced House Mice were recorded during the survey. This species is easily trapped in box traps. Limited survey effort was undertaken around the house and shed because of the presence of domestic Dogs, *Canis lupus familiaris* Linnaeus, 1758, and it is likely that House Mice occur in these areas from time to time. Probable mouse footprints were observed in fat on a barbeque at the shearing quarters. Most of "Murrayfield" is probably unsuitable for the native Swamp Rat, which occurs in wetter vegetation types and coastal heathlands (Hocking & Driessen 2000), but we thought that Swamp Rats might be recorded in vegetation adjacent to drainage lines. No Water Rats, *Hydromys chrysogaster* Geoffroy, 1804, were observed but the managers of "Murrayfield" advised that Water Rats have been seen at the mouth of Kirkby Creek (B. Michael, Murrayfield Station, pers. comm.). PWS rangers have also trapped a number of Water Rats at The Neck (B. Edwards, Parks and Wildlife Service, pers. comm.). Hird (2000) observed footprints of Water Rats on the coast near "Lauriston". No Common Ringtail Possums *Pseudocheirus peregrinus* (Boddaert, 1785) were recorded but the methods used did not specifically target this arboreal species. However, there was potential to observe their dreys or to spotlight them in trees. Hird (2000) observed a group of three Common Ringtail Possums crossing a road on northern Bruny Island in 1996.

Comparison of mammal survey methods

There are few studies that compare the effectiveness of survey techniques to detect mammals in Australia. Camera trapping is increasingly being used as a method for surveying mammals; however, there have been few studies comparing their effectiveness in surveying Australian mammals with other methods (De Bondi *et al.* 2010). Although our study was not specifically designed to compare survey methods some general comments are warranted as they may assist with the planning of future mammal surveys in Tasmania.

We found that Eastern Quolls and Brushtail Possums were widely recorded using camera trapping, cage traps and spotlighting. Whether similar levels of detection would be obtained at lower densities requires further investigation. In general, camera trapping and cage traps were similar in their ability to detect Long-nosed Potoroos. Where the two methods were used in similar locations, the cameras recorded potoroos at two locations where they were not trapped and cage trapping recorded potoroos at one location where they were not camera trapped. Spotlighting was not an effective way to monitor potoroos with only one individual observed and this is consistent with other spotlight surveys in areas where Long-nosed Potoroos occur (Driessen & Hocking 1992). Few pademelons were recorded on camera traps suggesting this method may not be effective for this species. Cameras were more effective at detecting Bennetts Wallabies than Tasmanian Pademelons but the low number of images recorded compared with other species also suggests that cameras or the baits used are not effective for detecting this species. Spotlighting appeared to be more effective in detecting both these macropods than cameras at least in the pasture and forest mosaic on "Murrayfield". It is possible that cameras may be more effective in large expanses of native vegetation in detecting these species. The only species caught in cage traps that was not recorded on cameras was the Cat which was recorded at the Saltmarsh where a camera was also located. Rabbits were only recorded by spotlighting.

A previous study has found that camera trapping is more cost-effective than live trapping terrestrial small mammal communities in Victoria, Australia (De Bondi *et al.* 2010). Although we did not calculate the resources used to undertake the different survey methods during our survey, it is clear that camera trapping is a more cost-effective survey technique than live trapping for detection of mammals on "Murrayfield". It is worth noting, however, that due to inherent difficulties in identifying individual animals from images, this technique is limited to providing information on presence/absence rather than abundance. Whether camera trapping is more efficient than spotlighting in detecting mammals will require further investigation but spotlighting failed to record Black Rats and is not effective in recording Potoroos and Short-beaked Echidnas.

MANAGEMENT CONSIDERATIONS

Key issues for the management and conservation of native terrestrial mammals include: vegetation clearance, degradation and fragmentation; introduced species; inappropriate fire regimes; unsustainable hunting; and disease.

One of the aims for the property is to balance the demands of running an established sheep and fine merino wool business with protecting cultural and environmental values. Large areas of "Murrayfield" have been cleared for pasture resulting in a mosaic of forest, woodland and pasture. This mosaic can benefit a number of native mammal species by providing increased food resources in the pasture (grasses and invertebrates) adjacent to shelter in the forest and woodland. This may be why Brushtail Possums, Tasmanian Pademelons, Bennetts Wallabies and Eastern Quolls were found to be abundant and widespread on the property. Two further species, the Southern Brown Bandicoot and in particular the Eastern Barred Bandicoot, can also benefit from the pasture/bush mosaic but were not recorded during the survey. Both species are easily detected by the methods used during the survey. Conditions on "Murrayfield" may be marginal for the Eastern Barred Bandicoot which are more common in high-quality agricultural land with deep soils and high rainfall (Driessen *et al.* 1996). Numbers of Eastern Barred Bandicoot are thought to be influenced by rainfall (Heinsohn 1966, Mallick *et al.* 2000) and the extended dry conditions on the island prior to the survey may have contributed to a lack of observations. It is also possible that the very high numbers of quolls are contributing to the absence of bandicoots. Eastern Quolls and bandicoots compete for the same food resources (invertebrates) and quolls may also prey upon bandicoots.

Although a number of native mammal species can benefit from a pasture/bush mosaic, many others require, or are restricted to, areas of native vegetation cover. "Murrayfield" retains large areas of native forest and woodland but some of the value of this habitat for native mammals has been degraded through unrestricted sheep grazing and clearing of undergrowth. Species recorded on "Murrayfield", or which have potential to be recorded, and are largely restricted to native vegetation are the Long-nosed Potoroo, Tasmanian Bettong and Swamp Rat. We recorded Long-nosed Potoroos at several locations on "Murrayfield" that, from casual observation (also see pl. 2), had limited grazing pressure and retained good levels of cover (e.g., Roberts Hill, Saltmarsh, Lodge Hill, Murrayfield). It would be reasonable to assume that other parts of the property supporting stands of *E. amygdalina*, *E. pulchella* and *E. obliqua* L'Hérit forest and woodland could support Long-nosed Potoroos if protected from grazing.

The lack of recorded Tasmanian Bettongs during the survey is puzzling because much of the forest and woodland on the Murrayfield property is consistent with typical habitat for this species (Driessen & Hocking 1990). The species is easily trapped and observed by spotlighting. The last official record of a Tasmanian Bettong on northern Bruny was in March 1974 by Hans and Annie Wapstra (Natural Values Atlas record). An animal resembling a bettong was caught during cat trapping near the homestead on "Murrayfield" early in 2010 (L. Michaels pers. comm., Murrayfield Station). Drought and limited firing of vegetation may be factors contributing to the absence of bettongs. The Murrayfield Native Vegetation Management Plan noted that (as of January 2005) there was little evidence of fires in the past 10 years. During our mammal survey in August 2010 we also noted little evidence of fires. There have not been any major wildfires on "Murrayfield" for at least 40 years (Murrayfield Fire Management Plan Draft 2008) and there has been no hazard-reduction or ecological burning on "Murrayfield" since it was acquired by the Indigenous Land Corporation in 2001. There is some evidence that bettongs can benefit from firing some vegetation types provided it does not occur too frequently (Johnson 1995, 1997). Fire can promote production of fruiting bodies of some subterranean fungi, the main food for this species (Johnson 1995). However, it is difficult to determine whether lack of firing is related to the apparent absence of this species on the property. The fire frequencies recommended for different vegetation communities on "Murrayfield" in the Murrayfield Native Vegetation Management Plan should be implemented to determine if it will benefit bettongs.

Swamp Rats require native vegetation cover with dense ground cover and primarily occur in wet forests, moorland and coastal heathland, but they also occur along drainage lines in drier parts of Tasmania (Hocking & Dreissen

2000). Suitable habitat for this species is very limited on the property although it would be reasonable to expect the species to occur along some of the drainage lines where there is a dense cover of cutting grass, *Gahnia grandis* (Labill.). Some creek lines have been cleared of vegetation that might have supported this species. We recommend excluding fire (and grazing) from riparian vegetation as also recommended in the Murrayfield Native Vegetation Management Plan.

Remarkably few introduced mammals were recorded during the survey. Black Rats were recorded in native vegetation at various locations on the property. There is little evidence to suggest that this species, although undesirable, displaces native rodents such as Swamp Rats. Remarkably, no House Mice, which are easily caught in box traps, were caught during the survey. It is possible that greater trapping effort around the shearing shed and houses would have resulted in captures of House Mice and more Black Rats. Workers on "Murrayfield" have observed and controlled cats and one cat was trapped during the survey at the Saltmarsh. Cats prey on native mammals but their impact on Tasmanian mammals has not been quantified. It could be argued that on an island with limited habitat cats may pose a greater threat to native mammal populations than on mainland Tasmania and perhaps they could be contributing, along with other factors, to the absence of species such as bandicoots and bettongs. Cats are the definitive host for the disease toxoplasmosis which can lead to death in native species particularly bandicoots (Obendorf *et al.* 1996). Although cats and bandicoots readily co-exist in Tasmanian mainland communities, it could be argued that the small populations on northern Bruny are at greater risk from toxoplasmosis.

Wallabies and possums are culled on the property to reduce their competition for food with sheep. There is no evidence to suggest that the current culling level is not sustainable. Controlling numbers of wallabies and possums should prevent build-up of large populations and high levels of grazing impacts on the native vegetation, as has occurred on Maria Island.

RECOMMENDATIONS

Management of mammals on "Murrayfield" primarily involves maintaining existing native vegetation and control of introduced animals. The Murrayfield Native Vegetation Management Plan divides the property into 11 management zones and provides detailed advice on managing vegetation as well as threatened fauna. In particular it identifies areas that should be fenced from stock, and fire regimes to be implemented for different vegetation types. Continued implementation of the vegetation management plan will be beneficial for the management of mammals on the property. In summary, it is recommended that:

- the Murrayfield Vegetation Management Plan continues to be implemented;
- the fire management plan be implemented;
- further areas of creek lines be protected from grazing;
- areas be identified, planted and fenced-off to increase connectivity between larger native habitat patches;
- cats continue to be controlled;
- surveys for bats be undertaken;
- monitoring of mammals be undertaken every five years;
- deadwood be maintained in native vegetation for nesting hollows for mammals;
- a register be kept of mammal observations, particularly of less common species; and
- fox sightings be reported.

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WOOD-INHABITING MACROFUNGAL ASSEMBLAGES IN 43-YEAR-OLD REGENERATING WET *EUCALYPTUS OBLIQUA* L'HÉR. FOREST

by Genevieve M. Gates, David M. Carpenter, David A. Ratkowsky and Patrick J. Dalton

(with six text-figures and five tables)

Gates, G.M., Carpenter, D.M., Ratkowsky, D.A. & Dalton, P.J. 2011 (9:xii): Wood-inhabiting macrofungal assemblages in 43-year-old regenerating wet *Eucalyptus obliqua* L'Hér. forest. *Papers and Proceedings of the Royal Society of Tasmania* 145: 65–76. ISSN 0080-4703. School of Plant Science, University of Tasmania, Private Bag 55, Hobart, Tasmania 7001, Australia (GMG*, DMC, PJD); School of Agricultural Science, University of Tasmania, Private Bag 54, Hobart, Tasmania 7001, Australia (DAR). *Author for correspondence. Email: Genevieve.Gates@utas.edu.au

This study focuses on the diversity and ecology of wood-inhabiting macrofungal species assemblages in a regenerating tall, wet, native *Eucalyptus obliqua* forest in southeast Tasmania, 43 years after natural and anthropogenic disturbances. Two plots subjected to "clearfell, burn and sow" silviculture were compared with two other nearby plots that had experienced wildfire. A total of 90 species was identified from 619 macrofungal records during six fortnightly visits between May and July 2010. The plots with abundant live *Pomaderris apetala* trees in the understorey (i.e., those at Edwards Rd) had markedly different macrofungal assemblages from those with no or with sparse *Pomaderris apetala* (i.e., at Hartz Rd). This study provided evidence that a 43-year-old regenerating forest maintains a core of common wood-inhabiting macrofungal species irrespective of type of disturbance. Furthermore, species most frequently observed in older forests in Tasmania can also occur in younger managed forests if biological legacies such as large diameter wood, well-decayed wood, large living trees and a diversity of tree species remain after silvicultural treatment.

Key Words: wood-inhabiting macrofungi, *Eucalyptus obliqua*, *Pomaderris apetala*, wildfire, managed forests, Tasmania.

INTRODUCTION

Maintaining wood-decay fungal diversity is an essential part of a productive forest ecosystem, and many studies have addressed the effect of anthropogenic disturbance on assemblages of wood-inhabiting macrofungal species in forests, especially in the Northern Hemisphere (e.g., Bader *et al.* 1995, Czederpiltz *et al.* 1999, Christensen *et al.* 2004, Heilmann-Clausen & Christensen 2005). Nevertheless, forest conservation programs of many countries still completely neglect fungi as an official conservation priority or even acknowledge their existence (Heilmann-Clausen & Vesterholt 2008).

The fruit bodies are the most obvious sign of the presence of a wood-inhabiting fungus. Macrofungal fruiting bodies on wood perform important habitat functions in their own right, providing food and shelter for a myriad of faunal species (Pavoir-Smith 1960, Pielou & Verma 1968, Schigel 2007, Robinson *et al.* 2008). Some polypore species are considered to be indicators of old-growth forest and important for the persistence of specialist insects (Komonen 2001). Macrofungal fruiting bodies can provide habitat and food for other fungal species inhabiting dead wood (Jonsson *et al.* 2005). Nutrients (Ca, Fe, K, Mn, N, P, Zn) can be exported via fruit bodies from the wood and returned to the forest floor by animals ingesting the fruit body, or by the senescence of the fruit body, which, for most fungal species takes only a few days to several weeks (Vogt *et al.* 1981, Harmon *et al.* 1994, Buchanan *et al.* 2001).

Esseen *et al.* (1997) and Penttilä *et al.* (2006) suggest that many of the negative effects of forest management activities on wood-inhabiting macrofungal species are a result of the simplification of the structure of these managed stands compared with natural unmanaged stands, as trees in managed regrowth forests are younger, smaller diameter, with smaller branches. Forest management also greatly alters the disturbance dynamics and results in a reduction and fragmentation of mature and old forests. The decline in the amount of dead wood, fragmentation of remaining natural dead wood habitats, and a change in the composition of the dead wood in current habitats have had dramatic effects on wood-inhabiting fungal communities (Heilmann-Clausen & Vesterholt 2008). Developing effective management protocols to minimise losses of macrofungal species depends on knowledge of what is an acceptable habitat loss or population reduction. This implies knowledge of the biological function and, in particular, the ecology of the individual fungal species (Arnolds 2001, Watling 2005).

In Australia, studies specifically on the ecology and diversity of wood-inhabiting macrofungi are few (see Fryar *et al.* 1999, Hopkins *et al.* 2011, Gates *et al.* 2011c) although wood-inhabiting macrofungi are generally documented as part of general macrofungal surveys (e.g., Packham *et al.* 2002, Robinson & Tunsell 2007, Robinson *et al.* 2008) without any attempt to analyse the data further. McMullan-Fisher (2008) undertook substrate fidelity analysis in her cryptogam study and concluded that there were suites of fungi with preferences either for small wood (≤5 cm diam.) or for large wood (>5 cm diam.).

The most widespread forest type in Tasmania is wet *Eucalyptus obliqua* L'Hér. forest (Public Land Use Commission 1996). At maturity, *E. obliqua* can frequently reach heights of over 70 m (Kirkpatrick & Backhouse 1981). Wet *E. obliqua* forests in Tasmania need disturbance to regenerate (Gilbert 1959). The most common type of natural disturbance is wildfire, the frequency and intensity of which are important in determining the nature of the future forest environment (Wells & Hickey 1999). A fire interval ranging from 20 to 100 years will result in the development of a wet sclerophyll forest community, whereas longer intervals of between 100 to 350 years result in mixed forest communities (Gilbert 1959, Wells & Hickey 1999). Fire intervals of greater than 400 years cause a maturation of rainforest understorey species to form a dominant canopy

which restricts eucalypt recruitment and after the senescence of the older eucalypts creates a characteristic temperate rainforest (Gilbert 1959, Jackson 1968).

The current silvicultural method in the wet eucalypt forests of southern Tasmania is "clearfell, burn and sow" (CBS) on rotations of 80–100 years (Hickey *et al.* 2001). The CBS method removes all living trees of value and a high intensity fire is then applied to the area which incinerates the logging slash waste and produces an ash bed which is highly favourable to eucalypt seed germination. This method was considered to mimic the effects of a natural wildfire disturbance which is essential in the regeneration of tall, wet eucalypt forests in Tasmania (Jackson 1968). This operation, however, leaves very few (if any) biological legacies such as stags, coppicing burnt trees or remnant patches of living forest (Lindenmayer & McCarthy 2002). It is suggested that CBS operations more likely mimic an extreme natural wildfire event or a succession of wildfires at short intervals, as described in Jackson (1968).

The macrofungal species that colonise after fire disturbance in Tasmania are very different from the group of species present in a predisturbed forest (Gates *et al.* 2005, 2009). The post-disturbance colonisation of substrates by macrofungal species is likely to occur more rapidly after a wildfire event in a wet *E. obliqua* forest than after a CBS operation due to the greater presence of biological legacies, i.e., organically produced patterns and structures (as mentioned above) that survive the disturbance.

The value of a small spatial scale study is that it provides baseline knowledge of an area in sufficient detail that can then be extrapolated to a larger landscape level. The accumulated knowledge from multiple small spatial studies has a use in assessing effects of habitat fragmentation on biodiversity. Furthermore, heterogeneity at the small-scale level may also indicate heterogeneity at a landscape level. Data analysis programs exist (see Holland *et al.* 2004) that can extrapolate small scale data into larger landscape level results leading to reduced costs (time, labour and travel) associated with intensive large-scale studies. Additionally, small spatial scale studies can gauge the success of specific habitat refugia, such as nature reserves and wildlife connectivity corridors.

The objectives of this study were to investigate the diversity of wood-inhabiting fungi in a 43-year-old regenerating *E. obliqua* forest by documenting the species numbers and species assemblages present, and to compare the effects of clearfell, burn and sow silviculture with the effects of wildfire on the wood-inhabiting fungi present in four plots. This is done within the context of an experimental design where two paired plots (one subjected to CBS and one which experienced wildfire) were examined at each of two localities in Tasmania's southern forests. The CBS regenerating stands are even-aged stands of 43 years, whereas the wildfire stands are of mixed age due to the erratic nature of wildfire in the tall, wet, *E. obliqua* forests of southern Tasmania (Alcorn *et al.* 2001, Turner *et al.* 2009). The opportunity also presented itself to investigate if a short-term study at this small spatial scale can provide data that can be incorporated into forestry management protocols. Specific questions relating to the above aims included whether there was a relationship between the macrofungal species diversity and the dead wood characteristics such as its species, decay class, diameter class, and whether the wood was fallen, suspended or upright. Also examined were whether the wood-inhabiting fungal assemblages depended upon vegetation type, soil pH, canopy and ground cover, and whether the diversity of the macrofungal assemblages on wood differed between the two disturbance treatments. We speculate about whether the findings from this study might influence the current use of CBS or alternatively, aggregated retention (ARN), a silvicultural procedure, in which "islands" of unharvested trees are retained for one or two rotations, under consideration for use in sustainable forestry in Tasmania. We further speculate whether there are any implications from this study on impacts on diversity of wood-inhabiting macrofungal assemblages from the intended harvesting of dead wood in Tasmania as a biofuel for power generation. We ask whether this short-term, small spatial scale study could reflect any results from similar, more intensive studies in *E. obliqua* forests of southern Tasmania, such as the one by Gates (2009).

MATERIALS AND METHODS

Study area, plot location and establishment

Four plots in native, tall, wet *Eucalyptus obliqua* forest in southern Tasmania, west of Geeveston were examined (fig. 1). All four plots, two from wildfire and two from a CBS forestry regeneration procedure, were part of larger forest tracts that had experienced disturbance in the years 1966/67. Two of these plots were directly opposite each other on either side of Hartz Rd, with the northern plot having been subjected to CBS regeneration and the southern plot having experienced wildfire. At Edwards Rd, the two plots were side-by-side on the north side of the road, the most easterly plot having been disturbed by wildfire in 1966/67, with the westernmost plot being a CBS plot. The four plots were used previously, along with other plots, as part of a study by Browning *et al.* (2010) on cryptogamic succession (mosses, liverworts and ferns) in these same regenerating wet eucalypt forests.

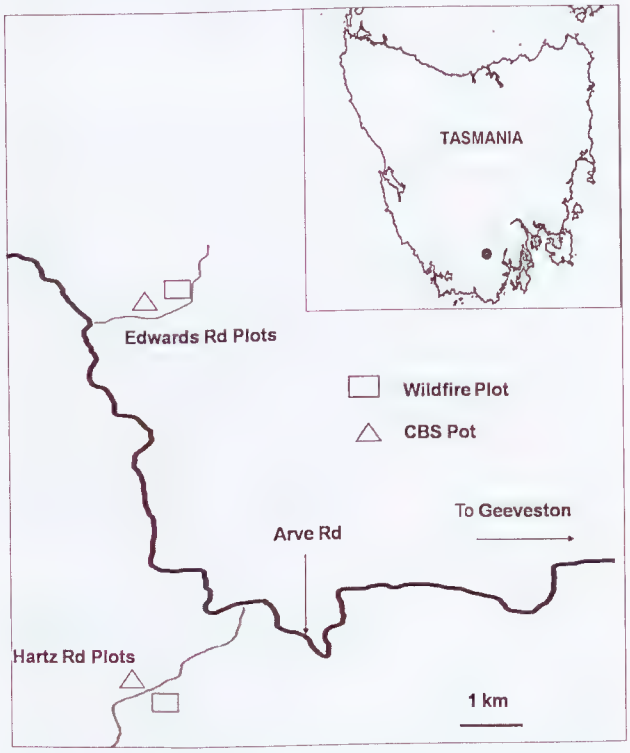

FIG. 1 — Map of site in southern Tasmania showing plot locations.

At each site (Hartz Rd and Edwards Rd), a 40 x 40 m plot was measured and marked out using twine, and each plot was divided into four 20 x 20 m quadrants.

Site characterisation

The slope, canopy cover, soil pH, ground cover and dominant vascular plants of each plot in the study were measured. The location of the chosen central point of each plot was determined with a handheld Garmin E-Trex®. The angle of slope was measured with a handheld Suunto® clinometer at three random positions within each quadrant. The 12 readings were then averaged to give an average slope for each site. The canopy covered by the dominant vegetation was measured at three random positions within each quadrant using a Forestry Suppliers Inc. Spherical Crown Densiometer®. At each position four observations (each facing north, south, east and west) were recorded. The averages of these readings were calculated to give a percentage canopy cover for each quadrant. Soil was sampled in three randomly generated locations within each quadrant. Samples were taken at a depth of 10–20 cm using a hand trowel, placed in a plastic bag and taken back to the laboratory for analysis using a Manutec® soil pH test kit to obtain an average soil pH for each quadrant. The percentage of ground covered by bare ground, litter, rock, bryophytes and dead wood separately was recorded at three random locations in each plot. For each component of ground cover, the percentage of cover was recorded as an absolute value and converted using a modified Braun-Blanquet cover class for analysing ground cover abundance data, as follows: 0=absent; 1=1–25%; 2=26–50%; 3=51–75%; 4=76–100%. The living stems of all vascular plants of height ≥1.5 m within each quadrant of each plot were identified to species using Eucaflip (Wiltshire & Potts 2007) and Treeflip (Wiltshire & Jordan 2009). The diameter at breast height (DBH) of each stem was measured using a diameter tape measure. From these measurements, the basal area of each tree and the percentages of basal area at the plot level occupied by each tree species were subsequently calculated.

Macrofungal survey method

Each quadrant was visited fortnightly from 6 May–15 July 2010, a total of six visits. This was determined to be the ideal time for collection, covering the optimal fruiting season for the majority of Tasmanian macrofungi (Gates & Ratkowsky 2009), where a macrofungus is defined as a fungus that may be seen with the unaided eye. In the first five visits a 20 m transect was followed in each of the four quadrants in a predetermined location and order. During the last visit (15 July 2010), each quadrant was surveyed randomly for 15 minutes. At each visit, the species binomial or "tag" name of each macrofungus observed on fallen wood or a stag within 1 m on each side of the transect was recorded. Resupinate species, if not readily identifiable, were ignored due to time considerations and lack of taxonomic expertise. For each species, only its presence (not its abundance) was recorded, and its substrate was classified according to its diameter class, decay class and plant species. Voucher specimens of known species, to be deposited in the Tasmanian Herbarium (HO), were collected at the first encounter and dried in an air dryer for 24–48 hours in the laboratory. All species new to the authors were macro- and microscopically described. Valid names were obtained from the website Index Fungorum (http://www.indexfungorum.org/names/names.asp, viewed November 2010). For each macrofungal species, the diameter class, level of decay and species of substrate was also recorded. For wood size, three diameter classes (small, D≤10 cm; medium, 10<D<40 cm; large, D≥40 cm) were used. The level of decay of each substrate was also classified into three classes– low, medium and high – based on appearance and structural stability using certain defined characteristics (table 1).

Statistical analysis

From the presence/absence data from the six fortnightly visits to each of the four quadrants of each of the four plots, species richness was calculated as the number of distinct macrofungal species observed. Randomised species accumulation curves were prepared to visualise the rate at which new species of wood-inhabiting macrofungi were observed over the study period, using the Mao-Tau estimator available in the package EstimateS (Colwell 2005). For species assemblages, non-metric multidimensional scaling (nMDS) and one of the routines (DISTLM) in the suite of programs for multivariate ecological data developed by M.J. Anderson and available as an add-on (PERMANOVA+) to PRIMER v6 (Clarke & Gorley 2006, Anderson *et al.* 2008) were used as inferential methods. DISTLM (and its associated plotting routine dbRDA) can be used on the macrofungal data recorded during the fortnightly visits because their use does not require any a priori distributional assumptions to be satisfied. Starting with the basic data tables of the presence or absence of each macrofungal species recorded on dead wood, similarity (resemblance) was defined using the Bray-Curtis measure (Bray & Curtis 1957). Significance levels were provided by permutation trials, using 9999 random permutations of the observed data set. The major question that was tested was

TABLE 1
Description of the characteristics assigned to each wood decay class

Decay Class	Characteristics
Low	Some to most of the bark is present; branches may retain twigs; wood is solid.
Medium	Bark is absent; log can be broken with some applied force, but is still structurally sound.
High	Log cannot support own weight; structure is soft and crumbly and can be broken or crushed easily by kicking; bryophytes, ferns and invading roots may be present.

whether there was an association between the macrofungal species lists obtained from each of the four quadrants of each plot and the living vascular plant species present in those quadrants. DISTLM uses two data matrices, one containing the Bray-Curtis resemblances among the macrofungal species lists in each of the 16 quadrants and the other containing the abundances of the vascular plant species present in those same quadrants. Conditional upon a significant P-value being obtained, DISTLM then establishes which of the vascular species best explained the differences among the macrofungal species assemblages at the quadrant level, and the graph available from dbRDA was used to visualise the differences.

RESULTS

Slope, canopy cover and soil pH

Table 2 summarises the mean slope, canopy cover and soil pH for the four plots. The slope of both plots at Edwards Rd was greater on average than at the Hartz Rd plots. The percentage canopy cover at all four plots was high with little difference between them, and the same was true of soil pH, the soils all being slightly acidic, with the difference in plot pH means being at most 0.5 of a pH unit.

TABLE 2
Site characteristics for each plot[1]

Site	Slope (°)	% Canopy cover	Soil pH
Hartz Rd CBS	21 (19–22)	87 (81–90)	5 (4–6)
Hartz Rd Wildfire	20 (14–33)	93 (92–94)	5 (5–5)
Edwards Rd CBS	35 (27–50)	92 (91–94)	5.25 (5–6)
Edwards Rd Wildfire	30 (25–33)	93 (93–93)	4.75 (4–5)

[1] Entries are plot means, with the ranges from the four quadrants given in parentheses.

Ground cover

There was little difference between the plots with regard to ground cover, with all plots having a large average cover of litter present (fig. 2). Both wildfire plots contained a slightly greater cover of dead wood on average than the CBS plots (fig. 2).

Vascular plant species composition

The total number of stems recorded over all plots was 2652 (table 3). The Edwards Rd CBS plot contained the most living stems of all plots with 1024 and the Hartz Rd CBS plot contained the least with 195 stems. The difference is mostly due to the large number of *Pomaderris apetala* Labill. at ECBS plus a smaller difference in *Olearia argophylla* (Labill.) F. Muell. ex Benth., which more than balanced the decreased numbers of *Nothofagus cunninghamii* (Hook.) Oerst. and of *Acacia dealbata* Link at that site. *Eucalyptus obliqua* was the dominant canopy species in all plots, with >50% basal area at each plot, although it was never the most numerous in terms of number of stems. Both Edwards Rd plots contained large numbers of *P. apetala*, which accounted for >40% of the basal area of those plots, to the detriment of rainforest species such as *N. cunninghamii*, *Atherosperma moschatum* Labill. and *Eucryphia lucida* (Labill.) Baill. This was in contrast to the Hartz Rd plots, which contained little or no *P. apetala*, but more rainforest species plus *A. dealbata*.

Macrofungal species richness

The six fortnightly visits yielded 90 species from 619 records on dead wood in the four plots surveyed. Of these, the 77 species believed to prefer wood as its substrate are listed in table 4 and were used in the subsequent statistical analyses. Table 4 also gives the number of records of each species, their wood decay class and diameter class, the plot in which they were recorded, the wood substrate species, and whether the wood was fallen, suspended, or a stag.

TABLE 3
Species of higher vascular plants with living stems of height ≥1.5 m, total number of stems and percentage basal area per plot (in parentheses), and total basal area of stems, in each of the four plots

	Plot identification			
Vascular plant species	HCBS	HWF	ECBS	EWF
Acacia dealbata	26(21.8)	23(11.1)	2(0.3)	5(2.6)
Atherosperma moschatum	6(0.3)	7(0.3)	2(0.0)	0(0.0)
Eucalyptus obliqua	41(66.7)	69(72.0)	50(53.2)	57(55.2)
Eucryphia lucida	0(0)	45(1.7)	1(0.7)	0(0.0)
Nothofagus cunninghamii	71(5.5)	638(14.6)	0(0.0)	0(0.0)
Olearia argophylla	23(3.9)	4(0.1)	154(5.7)	8(0.3)
Phyllocladus aspleniifolius	5(0.1)	3(0.0)	6(0.0)	0(0.0)
Pittosporum bicolor	1(0.1)	2(0.1)	0(0.0)	0(0.0)
Pomaderris apetala	22(1.6)	1(0.0)	809(40.1)	571(41.9)
Total stems (% BA)	195(100)	792(100)	1024(100)	641(100)
Stems total basal area (m^2/ha)	68.7	69.6	62.6	53.8

HCBS=Hartz Rd CBS; HWF=Hartz Rd Wildfire; ECBS=Edwards Rd CBS; EWF=Edwards Rd Wildfire.

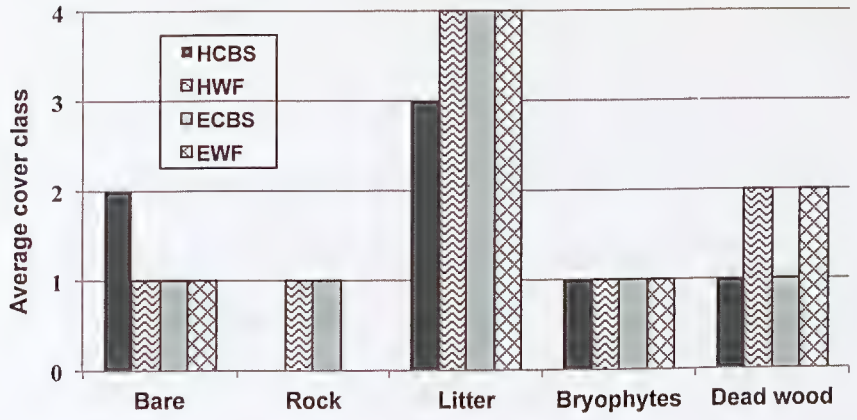

FIG. 2 — Average cover classes (modified Braun-Blanquet scores) for observed ground cover on each plot (HCBS=Hartz Rd CBS; HWF=Hartz Rd Wildfire; ECBS=Edwards Rd CBS; EWF=Edwards Rd Wildfire).

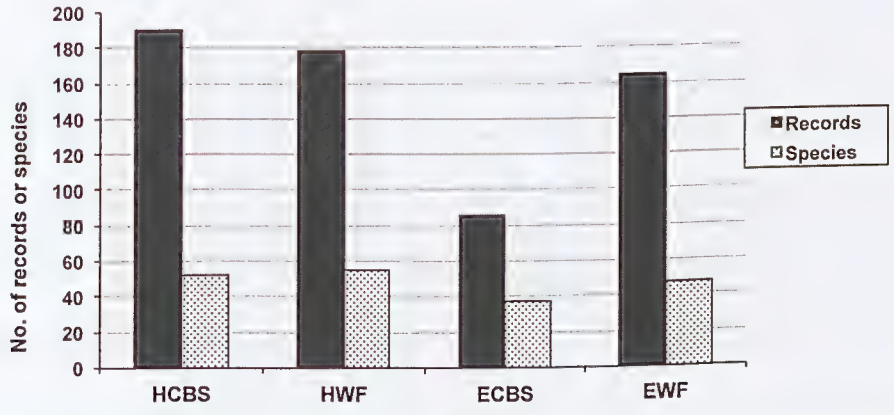

FIG. 3 — Number of records and number of species of macrofungi in each plot from six visits (HCBS=Hartz Rd CBS; HWF=Hartz Rd Wildfire; ECBS=Edwards Rd CBS; EWF=Edwards Rd Wildfire).

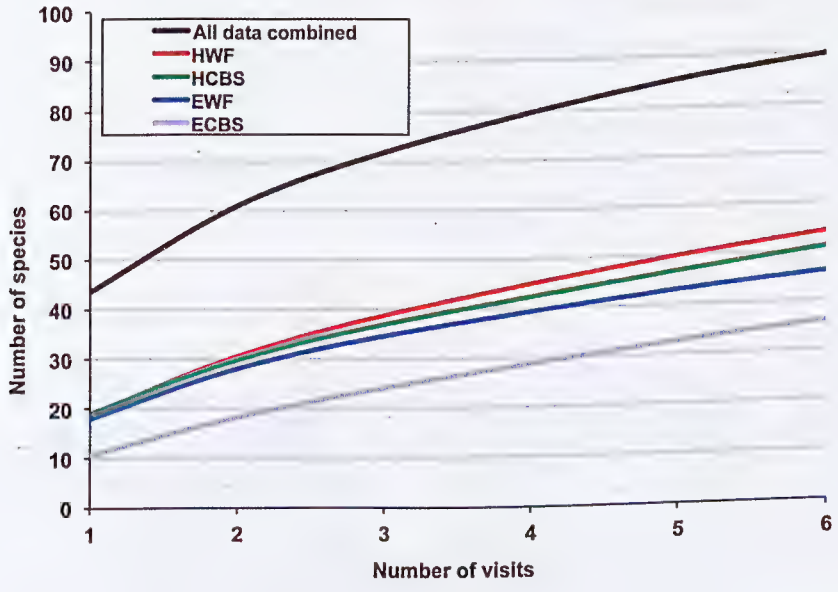

FIG. 4 — Randomised macrofungal species accumulation curves for each plot and for all plots combined (HWF=Hartz Rd Wildfire; HCBS=Hartz Rd CBS; EWF=Edwards Rd Wildfire; ECBS=Edwards Rd CBS).

TABLE 4

Compilation of the 77 wood-preferring macrofungal species collected during the survey. The records are classified by their wood decay class and diameter class, the plot in which they were recorded, the wood substrate, and whether the substrate was suspended, not suspended, or a stag

Macrofungal species	Total records[1]	Wood decay class[2]			Wood diameter class[3]			Plot identification[4]				Wood substrate[5]						Wood suspended?[6]		
		L	M	H	S	M	L	E_C	E_W	H_C	H_W	A	B	E	N	O	P	No	Stag	Yes
Amauroderma rude (Berk.) Torrend	1	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
Armillaria novae-zelandiae (G. Stev.) Herink	4	0	1	3	0	1	3	0	0	2	2	0	0	4	0	0	0	3	1	0
Ascocoryne sarcoides (Jacq.) J.W. Groves & D.E. Wilson	1	0	1	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1
Ascomycete "white brusing orange"	18	0	15	3	4	5	9	1	1	8	8	0	0	18	0	0	0	15	0	3
Australoporus tasmanicus (Berk.) P.K. Buchanan & Ryvarden	3	0	2	1	0	1	2	0	0	1	2	1	0	2	0	0	0	3	0	0
Biscogniauxia sp.	1	1	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1
Bisporella "green-yellow"	6	0	3	3	1	2	3	1	1	0	4	0	0	5	0	0	1	5	0	1
Bisporella citrina (Batsch) Korf & S.E. Carp.	5	1	4	0	2	2	1	2	0	0	3	0	0	5	0	0	0	5	0	0
Byssomerulius corium (Pers.) Parmasto≥	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0
Callistosporium "Maroon on wood"	3	0	2	1	0	0	3	1	0	1	1	0	0	3	0	0	0	2	0	1
Calocera "spathulate"	3	1	2	0	0	3	0	0	0	1	2	0	0	3	0	0	0	0	0	3
Calocera guepinioides Berk.	9	4	5	0	2	7	0	1	4	3	1	1	0	3	0	0	5	3	0	6
Chlorociboria aeruginascens (Nyl.) Kanouse	7	4	2	1	4	3	0	0	4	0	3	0	0	4	0	0	3	2	0	5
Clavicorona piperata (Kauffman) Leathers & A.H. Sm.	24	0	16	8	6	9	9	7	8	5	4	2	0	18	0	0	4	21	1	2
Clitocybula "Maria on wood"	1	0	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0	0
Collybia eucalyptorum Cleland	13	2	10	1	0	2	11	2	2	3	6	0	0	13	0	0	0	10	0	3
Crepidotus "orange"	2	0	2	0	0	1	1	1	0	1	0	0	0	1	0	0	1	0	1	1
Crepidotus nephrodes (Berk. & M.A. Curtis) Sacc.	6	0	2	4	3	3	0	0	2	3	1	1	1	3	0	0	1	3	0	3
Daldinia grandis Child	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0
Exidia sp.	1	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1
Galerina patagonica Singer	13	1	5	7	7	6	0	0	12	1	0	0	0	3	0	0	10	7	1	5
Ganoderma australe (Fr.) Pat.	2	0	1	1	0	0	2	1	0	0	1	0	0	2	0	0	0	1	1	0
Gloeoporus taxicola (Pers.) Gilb. & Ryvarden	2	1	1	0	0	0	2	0	0	1	1	1	0	1	0	0	0	2	0	0
Gymnopilus allantopus (Berk.) Pegler	6	0	5	1	3	2	1	0	2	3	1	0	0	5	0	0	1	3	0	3
Gymnopilus ferruginosus B.J. Rees	9	0	6	3	1	2	6	2	0	2	5	0	0	9	0	0	0	7	0	2
Gymnopilus tyallus Grgur.	3	0	3	0	0	2	1	0	0	2	1	0	0	3	0	0	0	1	1	1
Hericium coralloides (Scop.) Pers.	1	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	1	0
Heterotextus peziziformis (Berk.) Lloyd	18	11	7	0	13	5	0	2	6	7	3	0	0	16	0	0	2	10	0	8
Hohenbuehelia sp.	6	0	1	5	1	1	4	0	2	1	3	0	0	4	0	0	2	4	1	1
Hypholoma brunneum (Massee) D.A. Reid	2	0	1	1	0	2	0	0	0	0	2	0	0	2	0	0	0	1	0	1
Hypholoma fasciculare (Huds. : Fr.) P. Kumm.	24	1	17	6	6	12	6	5	1	10	8	0	0	24	0	0	0	17	0	7
Hypocrea megalosulphurea Yoshim. Doi	3	1	2	0	2	1	0	0	3	0	0	0	0	0	0	0	3	2	0	1
Hypoxylon aff. *placentiforme* Berk. & M.A. Curtis	16	7	7	2	6	9	1	3	13	0	0	0	0	1	0	0	15	8	0	8
Hypoxylon crocopeplum Berk. & M.A. Curtis	2	0	2	0	1	1	0	0	2	0	0	0	0	1	0	0	1	2	0	0
Junghuhnia rhinocephala (Berk.) Ryvarden	10	2	7	1	6	4	0	3	7	0	0	0	0	0	0	0	10	6	0	4
Lanzia lanaripes (Dennis) Spooner	5	3	2	0	5	0	0	0	2	2	1	0	0	5	0	0	0	1	0	4
Lentinellus pulvinulus (Berk.) Pegler	11	1	6	4	3	8	0	0	7	2	2	3	0	1	0	0	7	9	0	2
Marasmiellus affixus (Berk.) Singer	60	26	32	2	33	27	0	4	19	16	21	0	0	55	0	0	5	14	1	45
Melanotus hepatochrous (Berk.) Singer	11	8	1	2	4	5	2	0	3	5	3	1	1	9	0	0	0	3	0	8
Mollisia cinerea (Batsch) P. Karst.	2	0	2	0	1	0	1	0	0	0	2	0	0	2	0	0	0	1	0	1

Mucronella pendula (Massee) R.H. Petersen	3	0	3	0	0	0	3	0	1	0	2	0	0	3	0	0	0	3	0	0
Mycena "gelatinous grey frilly"	2	1	1	0	2	0	0	0	2	0	0	0	0	0	0	0	2	1	0	1
Mycena austrororida Singer	3	1	1	1	0	3	0	2	0	0	1	0	0	3	0	0	0	1	0	2
Mycena carmeliana Grgur.	17	3	12	2	2	10	5	5	1	7	4	0	0	15	0	0	2	8	0	9
Mycena interrupta (Berk.) Sacc.	41	7	25	9	14	25	2	7	5	16	13	0	0	35	0	0	6	9	1	31
Mycena kuurkacea Grgur.	21	5	14	2	8	10	3	9	3	7	2	0	0	15	0	2	4	11	0	10
Mycena maldea Grgur.	7	0	6	1	0	4	3	0	0	1	6	1	0	6	0	0	0	4	0	3
Mycena mulawaestris Grgur.	23	3	14	6	4	16	3	0	2	12	9	2	0	19	0	0	2	16	0	7
Mycena nargan Grgur.	2	0	2	0	0	2	0	0	0	0	2	0	0	2	0	0	0	1	0	1
Mycena subgalericulata Cleland	19	1	17	1	2	3	14	3	5	6	5	0	0	19	0	0	0	16	0	3
Panellus stipticus (Bull.) P. Karst.	1	0	1	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1
Pholiota multicingulata E. Horak	12	2	7	3	4	7	1	1	8	3	0	1	0	5	0	0	6	7	1	4
Pluteus atromarginatus (Konrad) Kühner	1	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1
Polyporus gayanus Lév.	3	0	2	1	2	1	0	2	1	0	0	0	0	0	0	0	3	0	0	3
Polyporus melanopus (Sw. : Fr.) Fr.	4	2	2	0	0	4	0	0	4	0	0	0	0	0	0	0	4	2	0	2
Postia dissecta (Lév.) Rajchenb.	8	0	7	1	0	8	0	1	0	5	2	0	0	8	0	0	0	4	1	3
Postia lactea (Fr.) P. Karst.	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1
Postia pelliculosa (Berk.) Rajchenb.	6	0	5	1	2	1	3	1	2	0	3	1	0	5	0	0	0	4	1	1
Postia punctata Rajchenb. & P.K. Buchanan	10	0	8	2	0	1	9	3	3	0	4	0	0	10	0	0	0	8	2	0
Postia subcaesia (A. David) Jülich.	2	1	0	1	2	0	0	1	1	0	0	0	0	0	0	0	2	1	0	1
Postia venata (Rajchenb. & J.E. Wright) Rajchenb.	2	0	2	0	0	1	1	0	0	1	1	0	0	2	0	0	0	2	0	0
Psathyrella "pale brown gills"	1	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0
Psathyrella echinata (Cleland) Grgur.	2	0	2	0	0	2	0	1	0	0	1	0	0	2	0	0	0	1	0	1
Psathyrella sp.	3	1	1	1	1	2	0	1	1	0	1	0	0	2	1	0	0	2	0	1
Pseudohydnum gelatinosum (Scop.) P. Karst.	2	0	1	1	0	2	0	0	0	1	1	0	0	2	0	0	0	1	1	0
Simocybe phlebophora E. Horak	2	0	1	1	2	0	0	0	2	0	0	0	0	0	0	0	2	2	0	0
Skeletocutis nivea (Jungh.) Jean Keller	4	0	4	0	2	2	0	1	0	1	2	1	0	1	0	0	2	1	0	3
Steccherinum ochraceum (Pers.) Gray	3	1	2	0	2	1	0	0	3	0	0	0	0	0	0	0	3	3	0	0
Stereum hirsutum (Willd.) Pers.	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	1	1	0	0
Stereum illudens Berk.	4	3	1	0	3	1	0	1	0	2	1	0	0	4	0	0	0	1	0	3
Stereum ostrea (Blume & T. Nees) Fr.	2	1	1	0	1	1	0	1	1	0	0	0	0	0	0	0	2	1	0	1
Stereum rugosum Pers.	25	17	8	0	13	12	0	0	8	8	9	0	0	24	0	0	1	13	0	12
Tremella fimbriata Pers.	1	1	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0
Tricholomopsis rutilans (Schaeff.) Singer	2	2	0	0	0	0	2	0	2	0	0	0	0	2	0	0	0	2	0	0
Tubaria rufofulva (Cleland) D.A. Reid & E. Horak	1	0	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1
Vibrissea dura G.W. Beaton & Weste	18	1	15	2	0	12	6	2	0	11	5	0	0	18	0	0	0	17	0	1
Xylaria castorea Berk.	1	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1
Totals[7]	619	142	367	110	204	278	137	86	165	190	178	22	2	472	3	2	118	349	17	253

Notes: (1) Total no. of records; (2) Wood decay class, L=low, M=medium, H=high; (3) Wood diameter, S=small, D≤10 cm; M=medium, 10<D<40 cm; L=large, D≥40 cm; (4) Plot ID, E_C=Edwards Rd CBS=ECBS, E_W=Edwards Rd wildfire=EWF, H_C=Hartz Rd CBS plot=HCBS, H_W=Hartz Rd wildfire=HWF; (5) Wood substrate, A=*Acacia dealbata*, B=*Bedfordia salicina*, E=*Eucalyptus obliqua*, N=*Nothofagus cunninghamii*, O=*Olearia argophylla*, P=*Pomaderris apelata*; (6) Wood suspended? No=on ground, Stag=dead standing tree, Yes=suspended in air; (7) All totals at the foot of this table include the records for 13 species considered to prefer litter or soil rather than wood, but which were found in association with wood in this study.

The two Hartz Rd plots had a similar number of macrofungal records and species, with the CBS and wildfire plots having 54 and 51 species, respectively (fig. 3). At Edwards Rd the diversity was lower in both plots, especially the number of species in the CBS plot (36 compared to 46 in the wildfire plot). In the randomised species accumulation curves (fig. 4), the distances between the curve for the data from all plots combined and the curves for the individual plots suggest that the commonality among the species in the different plots is not high, each individual plot containing some unique macrofungal species, the identities of which may be determined from table 4.

Macrofungal species assemblages

The species assemblages in the four plots were different, as shown by the first two axes of a 3-d nMDS ordination (fig. 5, stress=0.09). The figure clearly separates the assemblages in the Hartz Rd plots from those in Edwards Rd, but within Hartz Rd there is a fair amount of overlap between the macrofungi in the CBS and wildfire plots. This overlap is not resolved on the third axis (not shown). The results of DISTLM regression modelling using the first two dbRDA axis (fig. 6), reinforces the message of the nMDS ordination, with the two plots at Hartz Rd clearly separated from the Edwards Rd plots and from each other, but with the two Edwards Rd plots overlapping and not separated on the third dbRDA axis (not shown). The important predictor variables are summarised in table 5, which shows that the number of live *P. apetala* stems was the main indicator of differences among the plots, with the number of live *O. argophylla* stems being the second most important. The physical properties of the plot quadrants, viz. the soil pH, slope, canopy cover and the components of the ground cover, did not contribute significantly to explaining differences in the macrofungi found in the experimental units.

DISCUSSION

Macrofungal species richness

The total of 77 wood-preferring species (table 4) is high compared to the diversity found at other locations in Australia (Hilton *et al.* 1989, 40 spp.; Burns & Conran 1997, 13 spp.; McMullan-Fisher *et al.* 2002, 35 spp.; Robinson *et al.* 2003, 63 spp.; Robinson & Tunsell 2007, 68 spp.). However, those studies were in Western Australia, South Australia or Victoria, in different forest types and where the macrofungal fruiting season is shorter in their warmer, drier climate compared with Tasmania. Gates *et al.* (2011c), in a study conducted over a period of 14 months of fortnightly visits to a larger plot area (0.25 ha compared with 0.16 ha) not far from that of the present study, identified 308 species that can be classified as wood-preferring macrofungi. Of those 308 species, 69 were also found in this study. The remaining 239 species included many resupinate species, a group that due to time limitations could not be examined in great detail. In addition, Hopkins *et al.* (2011) found 91 putative operational taxonomic units (OTUs) from 18 living *E. obliqua* trees in an area close to the present study. However, that study was based on isolating fungi from the wood and identifying from cultures and from molecular techniques. Most of the OTUs could not be matched with a macrofungal fruit body and some may never form a fruit body during their life cycle. This further supports the notion that fungal diversity in *E. obliqua* forests is very high.

The number of species present in each of the quadrants, used as a measure of species richness, did not lead to a significant difference due to treatment (CBS vs. wildfire) in this study, as the low species numbers in ECBS compared with EWF at Edwards Rd was not matched by the results at Hartz Rd (see fig. 3). Similarly, Browning *et al.* (2010) found that species richness of mosses, liverworts and ferns on coarse woody debris was not significantly different in CBS and post-wildfire 43-year-old plots in this same forest.

TABLE 5
DISTLM modelling using a stepwise procedure, showing the significant explanatory variables for the macrofungal assemblages

Explanatory variables entered	P-value	Cumulative R^2 explained
Pomaderris apetala	0.0006	0.159
Olearia argophylla	0.0420	0.257
Phyllocladus asplenifolius	0.0219	0.357

Macrofungal species richness – substrate species

A noteworthy result from the present survey is the fact that 95% of the 619 macrofungal records occurred on only two substrate species, viz. *Eucalyptus obliqua* (76%) and *Pomaderris apetala* (19%). Only three records (0.5%) occurred on *Nothofagus cunninghamii*, a sharp contrast to South America and New Zealand, where *Nothofagus* forests are the supporters of many native macrofungal species (for New Zealand, see McKenzie *et al.* 2000). In Tasmania, wood-inhabiting polypore species found on *Nothofagus* in South America (Rajchenberg 2006) prefer eucalypt wood rather than *Nothofagus* (Gates *et al.* 2011c). Evidence from previous surveys suggest that eucalypt-dominated forests are also rich in ectomycorrhizal macrofungal species in soil (Gates *et al.* 2011a) and in litter (Gates *et al.* 2011b). Further evidence comes from Western Australia (Robinson & Tunsell 2007), where there are no extant *Nothofagus* species, but which did occur in the past as a legacy from Gondwanaland (Bougher *et al.* 1994, Carpenter & Pole 1995). The modern Western Australian forests that are rich in macrofungi are dominated either by *Eucalyptus diversicolor* F.Muell. or *E. marginata* Sm., which is evidence that, in Australia, eucalypts may be the major vascular plant host of macrofungi. In the present study, *Pomaderris* was an important secondary host to *Eucalyptus*, with 35 species found on *P. apetala*, of which 13 were found only on this species (table 4). This reinforces the finding from Gates *et al.* (2011c), where fallen and suspended *P. apetala* occurred abundantly in two of the four plots surveyed and supported 85 macrofungal species of which 33 were only on that substrate. Fallen *P. apetala* produces a lot of small to medium diameter wood in the low or medium decay class, which can support what Rayner & Boddy (1988) refer to as "latent invader" fungi, an example of which is *Hypoxylon* aff. *placentiforme* Berk. & M.A. Curtis, found frequently in this study. Also, as *P. apetala* has a very smooth bark, it may

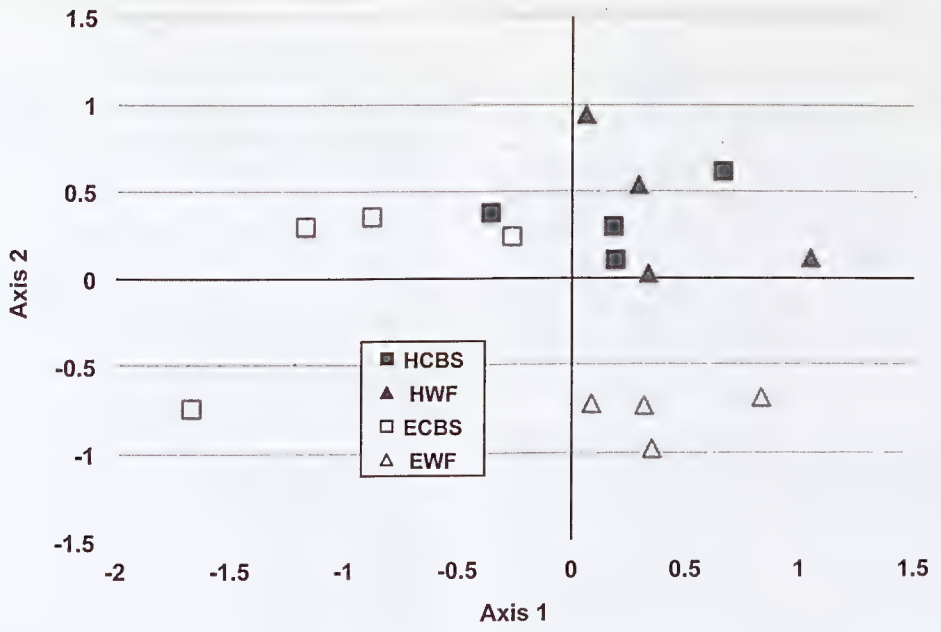

FIG. 5 — The first two axes of a three-dimensional non-metric multidimensional scaling ordination applied to the Bray-Curtis resemblance matrix obtained from the macrofungal species assemblages observed during the six visits (stress = 0.09) (HCBS=Hartz Rd CBS; HWF=Hartz Rd Wildfire; ECBS=Edwards Rd CBS; EWF=Edwards Rd Wildfire).

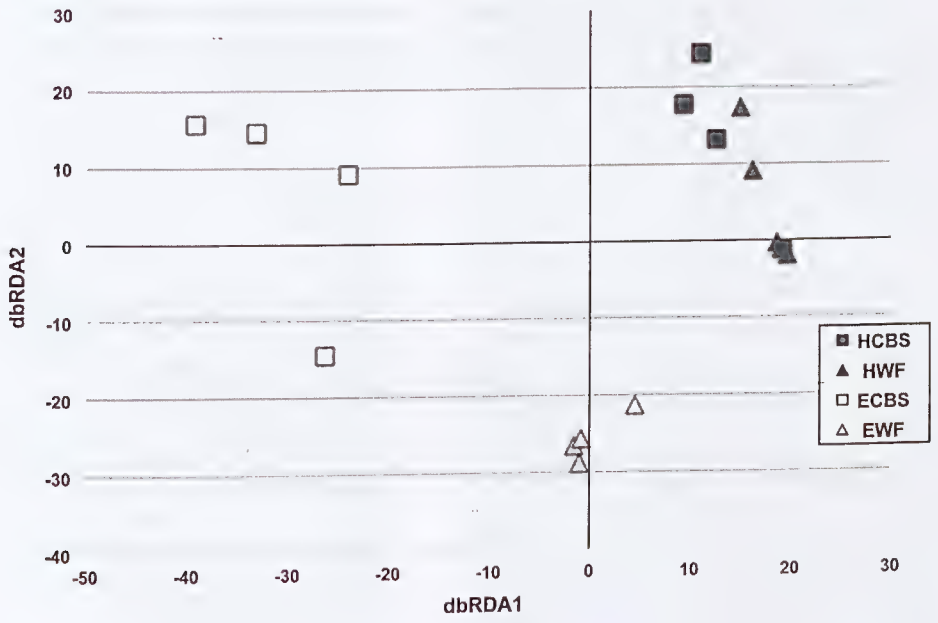

FIG. 6 — dbRDA graph of best DISTLM model, the points representing the macrofungal species assemblages pooled over six visits in four quadrants of each of the four plots (HCBS=Hartz Rd CBS; HWF=Hartz Rd Wildfire; ECBS=Edwards Rd CBS; EWF=Edwards Rd Wildfire).

present a more favourable surface for spore colonisation to some species of fungi (see Renvall 1995).

Macrofungal species assemblages – influence of site variables

The vascular plant community was shown to have a significant effect on the macrofungal assemblages found (table 5, figs 5 & 6). The important influence of the vascular plant communities was also shown for the southern wet *E. obliqua* forests of Tasmania by Packham *et al.* (2002), who found a distinct difference between the macrofungal assemblages in mature (generally long unburnt) and regrowth (recently burnt) forests.

Some further observations

Table 4 includes several species usually associated with old forests in Tasmania. These species occur either on large diameter wood, highly decayed wood, or are host specific. They are not confined to any one plot in this study but are found on biological legacies from a predisturbed stand irrespective of type of disturbance. For example, *Hericium coralloides* (see table 4 for naming authorities of the fungi) was found on a well-decayed stag of *N. cunninghamii* in the Hartz CBS plot, and *Australoporus tasmanicus* was found on a large diameter log in a high decay class in the Hartz wildfire plot. The common brown heart-rot fungus *Postia punctata* was present in all plots (mostly on large diameter wood in a medium decay class) except for Hartz CBS but even so it was noted on a very large *E. obliqua* log outside of the plot area but still within the CBS coupe. *Postia subcaesia* was the only heart-rot fungus found on small diameter wood. This fungus usually forms small fruit bodies, and a small fungus shouldn't require a large spatial domain, according to Rayner & Boddy (1988). Similarly, the small fruit bodies of *Skeletocutis nivea*, *Gloeoporus taxicola* and *Junghuhnia rhinocephala* were found only on small or medium diameter wood, with the last species being confined to *P. apetala*. In Tasmania, *J. rhinocephala* has not yet been found on any other wood species, although in the Melbourne Herbarium (MEL) there are collections of it occurring on *Acacia* species. Four *Stereum* species, viz. *S. ostrea, S. illudens, S. rugosum* and *S. hirsutum*, were absent from large diameter wood in a high decay class. This is consistent with their known existence as latent invaders of sapwood and as some of the first fungi to appear on freshly downed wood. *Galerina patagonica* was predominantly found on small and medium diameter wood in the medium and high decay classes (as in Gates 2009), with only a single record on wood in a low decay class in the current study. Generally, however, the agarics, in particular the majority of the *Mycena* species, were spread across all wood diameter sizes and decay stages as observed by McMullan-Fisher (2008) and Gates (2009). A notable exception is *M. subgalericulata* which commonly fruits on large diameter living *E. obliqua* trees (Grgurinovic 2003) and continues fruiting on the fallen large diameter wood. Species very commonly found in old *E. obliqua* forests, such as *Pluteus* spp., *Pleurotus purpureo-olivaceus*, *Plectania campylospora*, *Psilocybe brunneoalbescens*, *Hypoxylon bovei* var. *microsporum*, *Fomes hemitephrus* and *Tyromyces merulinus* were not observed. This could be related to the short duration of the study, the small area surveyed or, in the case of the CBS plots, the lack of biological legacies.

Implications for sustainable forestry management

The results of this study can assist in developing protocols for sustainable forestry management in Tasmania. The current silviculture process of CBS removes large living trees which would eventually end up being large dead wood in the natural cycle of a wet *E. obliqua* forest. Wildfire disturbance being non-stand replacing in these forests (Alcorn *et al.* 2001, Turner *et al.* 2009) and at intervals of ca. three fires per century leaves either large stags, which are the next input of large dead wood, or living trees which are not killed by the fire. Our results show that there is a number of species of macrofungi (e.g., *Australoporus tasmanicus* and *Ganoderma australe*) which are only found fruiting on large diameter wood. This suggests that biodiversity of a predisturbance stand (as measured using fruit bodies) can be maintained in a 43-year-old forest, irrespective of whether it is regenerating after CBS silviculture or as a result of wildfire, providing there is sufficient large dead wood remaining after disturbance and that conditions are conducive to fruit body formation. This study could also assist in assessing the impact of the currently trialled alternative silviculture treatment to CBS in southern Tasmania, i.e. ARN, where "islands" of predisturbance habitat are retained to maintain biodiversity. The removal of all dead wood for biofuel could affect wood-inhabiting fungi; however, it is not known how much dead wood is necessary to retain in each decay stages and size class. The important point from this study is that retaining dead wood of all sizes and decay stages is necessary to maintain wood-inhabiting macrofungal diversity irrespective of whether it is a wildfire or a silviculture disturbance and should be part of sustainable forestry management protocols for the wet *E. obliqua* forests of southern Tasmania.

CONCLUSIONS

We conclude that:

- Dead wood of different sizes and stages of decay is a substrate for a rich and diverse assemblage of macrofungal species, supporting the finding of Gates (2009).
- A short-term study in these forests, such as the current one, can provide informative data.
- The presence of *Pomaderris apetala*, which was very abundant at the Edwards Rd plots but very sparse at the Hartz Rd plots, significantly influenced the macrofungal species assemblages, supporting a suite of species not found on other substrates.
- The low number of macrofungal species fruiting on *Nothofagus* is surprising, in view of the importance of that genus in New Zealand and South America as a substrate for wood-inhabiting fungi.
- The results of this study on wood-inhabiting macrofungi complement those of Gates *et al.* (2005, 2011c), adding an age since wildfire (43 years) not considered in the earlier studies. It also had anthropogenic disturbance as a comparison.
- Further studies in forests at different ages of regeneration are needed before and after both natural and anthropogenic disturbance to obtain a better picture of the effects of disturbance on macrofungal diversity in these forests.

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